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AIR POLLUTION CONTROL ASSOCIATION

Founded 1907

August 1961
Vol. 11, No. 8

Airview of Downtown Louisville, Kentucky. (See page 394.)

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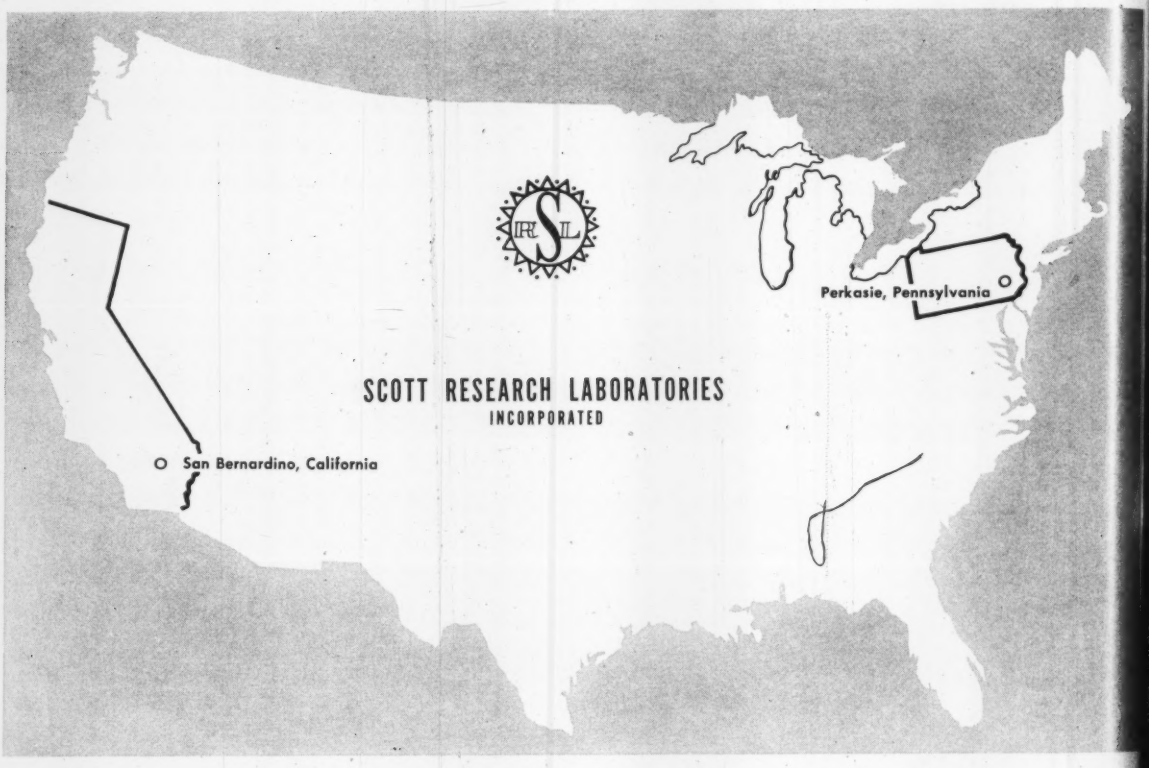

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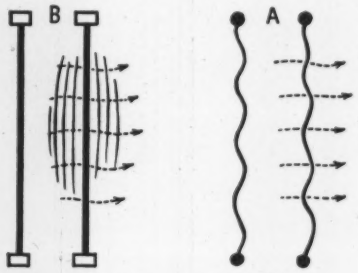

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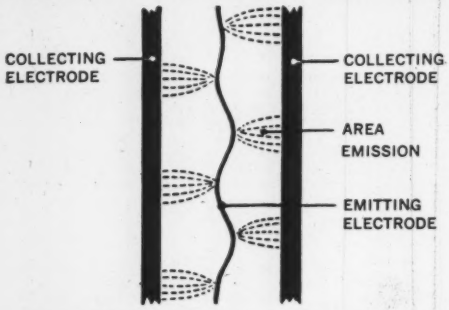

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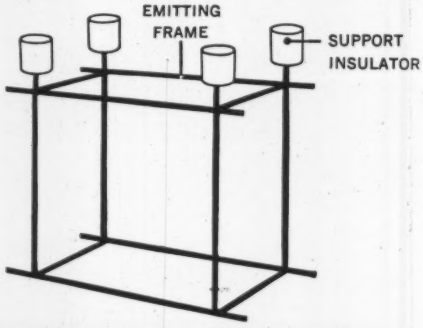

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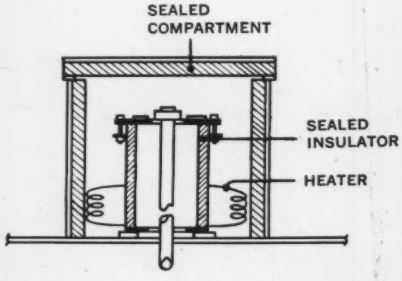

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JOURNAL OF THE AIR POLLUTION CONTROL ASSOCIATION

A Monthly Journal
Devoted to
Air Purification

Editor: Arnold Arch
Associate Editor: Pat Truschel
Assistant Editor: Pat Martin

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The Editor welcomes writers interested in air pollution problems and encourages them to use the pages of this journal for the expression of their opinions. But neither he nor the Association assumes responsibility for the validity of the opinions expressed herein.

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LETTERS to the EDITOR

TI-7 Report

Editor:

We must take exception with Reports Nos. 5 and 6 of Committee TI-7 which appeared in the May 1961 issue of the APCA Journal. These reports reject the use of opacity measurements. Section 24242 of the California State Health and Safety Code has been in existence for almost 14 years. Thousands of enforcement actions have been taken using this rule as a basis. The courts have upheld its constitutionality.

We have experienced no difficulty in training inspectors in the use of part (b) of this rule. It is a most effective tool in air pollution control work. Rejection by APCA of this important enforcement weapon is a step backward.

We urge APCA to reconsider its position.

Very truly yours,
S. SMITH GRISWOLD
Air Pollution Control Officer

Editor:

I am writing in regard to "Informative Report, Number 6 of Committee TI-7 (Ferrous and Nonferrous Foundries)," which was published in the May 1961 *Journal*. I would like to object to part of a section of that report which is subtitled, "Ordinances Which Restrict Stack Discharges by Comparing Their Opacity with the Ringelmann Chart or Other Visual Smoke Inspection Guides."

The authors of this report apparently are not aware of the effectiveness of certain local enforcement measures which have played and still are playing a great part in bringing about substantial reduction in emissions from foundries and other sources of visible air pollution which is light in color.

I agree that it is preferable from an engineering standpoint to enact statutes which relate emissions to process weight from sources such as foundries, where air pollution cannot be effectively controlled by changes in operation. Continuous enforcement of such rules, however, requires that stack testing be conducted (at the knowledge of the company involved). It would often be impossible, under this type of statute, for evidence to be obtained of excessive emissions due to improper maintenance or operation.

In regions where no coal is burned, visible contaminants of light color are as important or more important than black or dark emissions. There is certainly no a priori reason why a statute setting a reasonable limit on opacity cannot be enacted to cover any visible emission. For the statute to be effective, a field inspector must learn to read smoke opacities against a standardized smoke indicator, but this procedure is not unfeasible and has been used with much success in both the Los Angeles and San Francisco Bay areas.

Very truly yours,
PHILIP S. TOW
Air Sanitation Engineer

President's Message

Let's Talk APCA

When I returned to my desk shortly after the Annual Meeting in New York, a letter awaited me. It was from a comparatively new member of APCA, an industrial executive, who had just attended his first Annual Meeting. He said: "I was favorably impressed with the apparent vigor of the organization; with the degree of interest which seemed to be shown by those who were present; by the interesting heterogeneity of those in attendance, which, I believe, is one of the strengths of the organization; and by the apparently satisfactory quality of the technical papers which were presented. I don't pretend to be a competent judge of technical competency in this field, but I concluded the speakers must have known what they were talking about. All in all, it seemed to me that it was a good meeting and served well its primary purpose of providing a place where control officials, interested citizens, and industry representatives concerned with air pollution matters can meet for unemotional discussions of the facts of life in the air pollution field."

If he is right, and I think he is, APCA right now should be an organization of 5000 members, instead of 2000. It can be if every member of APCA will tell his friends and colleagues about the organization. Tell your friend of the nature of our annual meeting, our various sectional meetings, our monthly journal (with the best cross-section of technical and nontechnical air pollution articles appearing anywhere); our monthly *Abstracts*, which cover all important a-p articles, foreign and domestic. Tell him of the special information services available from our headquarters office at Mellon Institute; the industry-by-industry reports prepared by our Technical Committees. Then invite him to become a member. (Better get some application blanks from Headquarters first.)

In addition to these services from APCA to the membership, we offer all members the opportunity to do something for APCA through service on our various committees. In this connection, I promise that any member of APCA who wants to work on a committee and lets me know will be so appointed, perhaps not to the committee of his choice but at least to one where he can help.

The President of APCA can do only a few things. He can appoint; he can urge. He is no dictator (nor is any other officer or appointee). With the approval of the Board of Directors, he can make and rescind appointments. Without anyone's approval he can urge the membership to action. This I intend to do on the President's Page, at least every other month.

This month I urge you to talk up APCA and help increase our membership.

W. L. FAITH

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AIR POLLUTION CONTROL ENGINEER — Graduate chemical or mechanical engineer with two years air pollution or related experience. Write: San Bernardino County Civil Service, Courthouse, San Bernardino, California.

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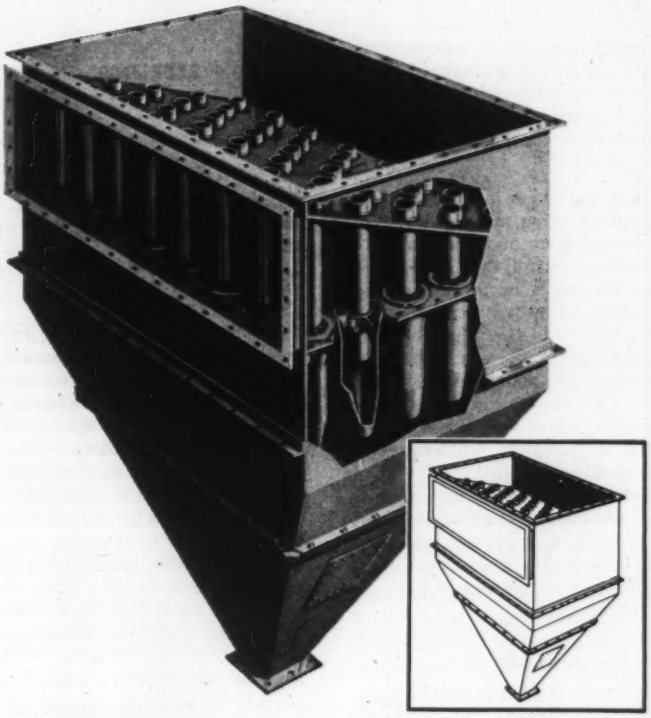
Catasauqua, Pennsylvania

Magill, Paul L.
Los Altos, California

(*Continued on p. 389*)

New Ideas On Dust And Fume Control



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New collector tube and inlet vane designs in the John Wood Cyclone Collector result in sharply increased operating efficiency. These improvements enable the John Wood engineered equipment to provide the uniform gas flow to each cyclone and to assure the high centrifugal force necessary to remove even the smallest particle sizes.

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Air Pollution CONTROL *and the* GAS INDUSTRY*

MORTON STERLING, Chief, Bureau of Air Pollution Control, Detroit, Michigan

The use of gas in space heating, service water heating, and power generation is looked upon quite favorably by air pollution control officials because gas generally can be burned in a smokeless manner. However, this seeming attractiveness in these applications should not permit the gas industry to be unconcerned about air pollution control. Gas is used in many other applications where severe local, or area-wide air pollution problems could result; such as in heating of varnish kettles, heat treating or annealing of metals, secondary smelting of nonferrous metals, kiln drying operations, and the incineration of waste materials. This latter application will be the main subject of this paper.

Bureau Responsibilities

The Detroit Bureau of Air Pollution Control is responsible for carrying forth a comprehensive preventive and corrective program for improving and/or maintaining the purity of the atmosphere. Control efforts are not restricted to industrial activity only, for it is recognized that the general public greatly contributes to the over-all air pollution problem. It is estimated that public activities account for up to 40% of the pollution in the Detroit area by the operation of home heating equipment, vehicle operations, and refuse burning equipment.

In view of this, the improper burning of fuel in the home receives as much attention from the bureau as the improper burning of fuel in commercial activities. The bureau restricts the sale of coals to be used in hand-fired coal boilers to meet certain stipulated standards of performance, specified in the air pollution control ordinance. The operation of private and commercial motor vehicles has come under careful scrutiny during the past three years, and vehicle smoke performance must conform to strict standards which were jointly developed by the bureau and the Automobile Manufacturers Association. The domestic incinerator, therefore, rightfully deserved some specific attention.

Origin of Interest in Domestic Incinerators

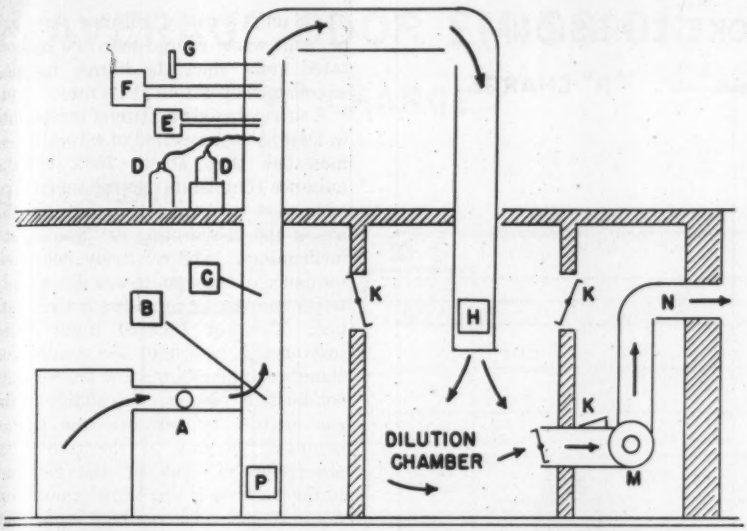
Our interest in controlling emissions from the operation of domestic incinerators was a natural outgrowth of our all-inclusive control activities, and was highlighted by the concurrent interplay of two major factors—one was the desire of the city to encourage residents to dispose of their household refuse on their premises by the use of garbage grinders and/or incinerators due to the limited available municipal waste disposal facilities, and the other was the increasing dissatisfaction expressed by the average citizen on the general performance of the domestic incinerator from an air pollution nuisance standpoint.[1] It therefore became necessary that a publicly acceptable incinerator be made available if the "on-the-site" disposal program were to be successful. To insure that such devices were developed, a supplementary air pollution control ordinance was passed in 1956, which became effective in early 1957. This ordinance limited the sale of domestic incinerators to those models which passed bureau performance requirements. The problem now resolved itself into developing standards of performance which would improve the operational characteristics of the domestic incinerator and, at the same time, alleviate the local nuisance problem generally caused by their operation.

Development of Domestic Incinerator Regulations

It became apparent to the gas industry that this was an opportune time to assist the local air pollution control agency to develop reasonable regulations regarding the operation of a gas-operated appliance. Mainly through the efforts of the local gas utility and a special subcommittee of the Gas Appliance Manufacturers Association, a series of meetings was held with bureau personnel to discuss the general facets of the air pollution problem caused by the operation of domestic incinerators. It was quite obvious in the initial discussions, that there was a wide diversity of opinion between the gas industry and air pollution control representatives on what should constitute minimally acceptable performance requirements. However, it also became obvious that if any progress were to be made on the development of such standards, concessions would have to be made by both parties. As a result, the regulations which were finally adopted were a compromise between what the city believed it wanted and what the gas industry believed it could develop practically. The requirements were sufficiently restrictive to preclude the possibility of the then marketed incinerator from passing the new performance requirements. However, this step immediately placed the city in the possible conflicting position of promoting "on-site" disposal without an available approved incinerator. It, therefore, again became necessary to compromise to meet mutually desirable goals, and various restrictive provisions of the regulations were staggered on a preselected time schedule to permit the manufacturers ample time to develop and test new models without wholly restricting their sale. This approach permitted attainment of our requirements without creating undue hardship on all interested parties.

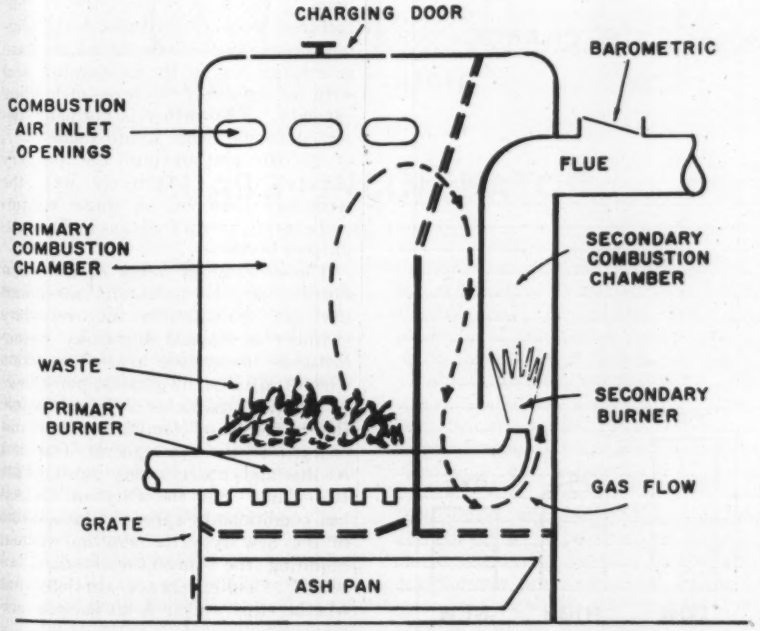
The foregoing approach to this problem may appear to be too "pat" to many of you; however, upon reflection, it must be conceded that many problems which at first appear to be insurmountable are actually relatively simple to solve. The key to success is the willingness to discuss openly the differences of opinion and the matters of mutual concern. I understand there is apprehension among some that air pollution control officials are sometimes not open to discussion. As an active member of this group, I do not believe this to be the general case. It is acknowledged that in some instances greater initiative will be required on your part to achieve desired goals. In the final analysis, the air pollution control official must recognize that he has an equal responsibility to listen and weigh carefully representations from

* Presented at the American Gas Association Research and Utilization Conference, April 19–21. 1960, Cleveland, Ohio.



A. Barometric Damper
B. Flue Gas Temperature Recorder
C. Draft Recorder (Static Updraft)
D. Flue Gas Sampling Bottles
E. Velometer
F. High Volume Sampler
G. Pyrometer
H. Smoke Observation Window
K. Adjustable Dampers (Dilution Air)
L. Adjustable Dampers (Draft)
M. Draft-Inducing Fan
N. Outlet for Diluted Flue Gases to Odor Panel
P. Clean-out Door

Fig. 1.



TYPICAL NEW INCINERATOR

Fig. 2.

industry, just as he does those from the public.

Incinerator Performance Requirements

The stipulated domestic incinerator smoke limitations are similar to the general air pollution requirements. Since the smoke emission from domestic incinerators is normally bluish white, the standard Ringelmann limitations could not apply. The smoke evaluation procedure was therefore based on equivalent Ringlemann readings and a standard smoke unit scoring system[3] was favored (Appendix I). Any smoke emission up to and including eight smoke units per 30 min (equivalent to four minutes Ringelmann No. 2 in 30 min) was acceptable. Number 1 Ringelmann was exempted from consideration. After considering several automatic measuring and recording techniques, it was decided that visual observations through transparent section of the exit flue (before dilution) with appropriate lighting were satisfactory for our purposes. We have not experienced any difficulty using this method.

The fly ash particulate limitations are in accord with our general air pollution regulations, i.e., 0.30 gr/cu ft corrected to 500°F and 50% excess air. Early in the development of the special domestic incinerator regulations, it was thought that a particle-size limitation should also be included. The bureau's desires were overruled by the Department Appeal Board, since they felt that this added restriction was not in effect for other combustion or process systems.

The odor limitations are simply written but not so simple to evaluate. The regulation states, "The odor at the test location shall not be more objectionable than the odor from the burning of two sheets of newspaper in an open fire with approximately the same percentage of dilution air."

After considerable discussion on the interpretation of this requirement, it was felt that some allowance should be given for a limited time for odor emission more than stated, just as is commonly tolerated in smoke limitations. A three-minute period was allowed for the odor to be more objectionable than the reference odor. A five-member odor panel was selected to make the odor evaluation. A scoring technique was devised to express the odor panel's subjective response as a number[6–7] (Appendix I).

Incinerator Design Features

The old model incinerators fall into two major categories—the so-called "low input" or dehydrating type and the "high input" class.[4] The term "low input" is in a sense a misnomer.

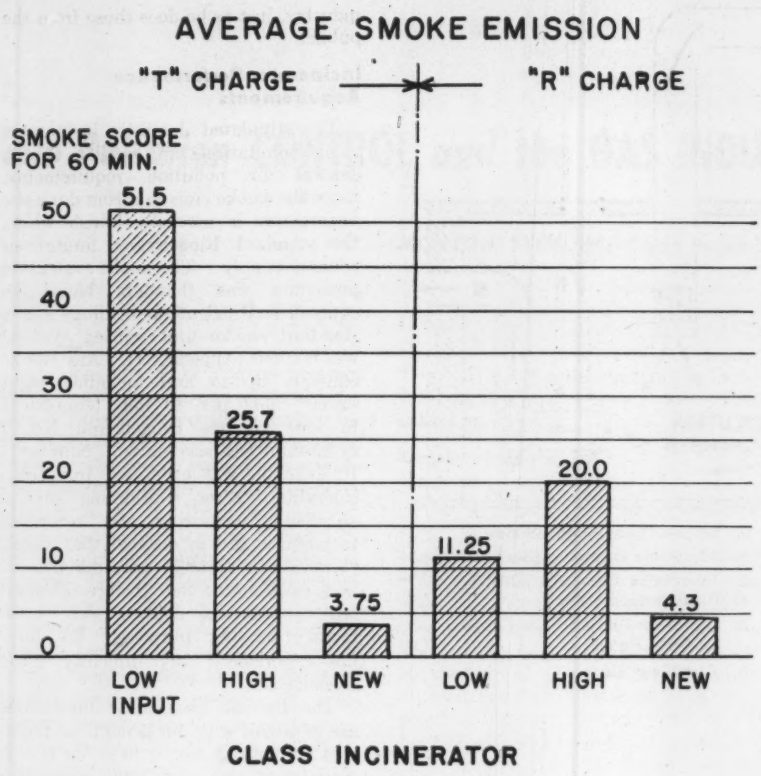


Fig. 3.

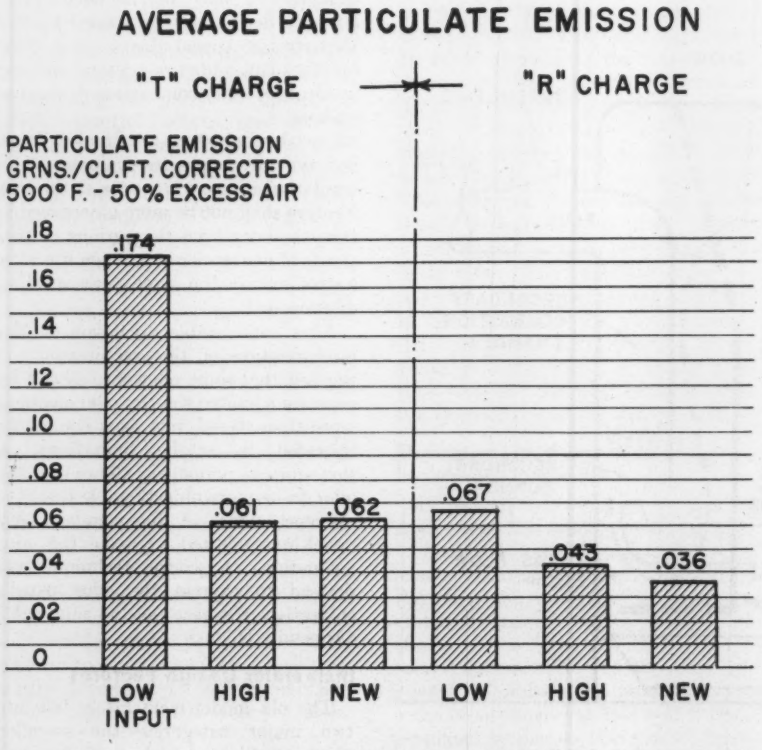


Fig. 4.

These units actually consume more gas per unit waste charge than the higher-rated units, since the burner remains in constant operation at its rated input.

A survey based on citizens' complaints in Detroit over a period of several years indicated that about 75% of the nuisance complaints against smoke and odor were directly attributable to the use of the dehydrating or "low input" incinerators. The relatively poor performance of these units was due mainly to the smoldering condition in the waste bed. The low thermal input added just enough heat into the combustion chamber to maintain a low temperature combustion process. In addition, the gas mixture temperature was further depressed because of the continuous absorption of heat by the moisture in the waste as it was transformed from liquid to gas. The old high input unit, with its burner near the grates and simple up-draft combustion chamber design, often caused a more dense smoke emission for a shorter time. For periods of a half hour or more after being charged with a heavy garbage load, the submerged burner often caused voluminous clouds of malodorous smoke to be distilled out of the moist mass above it.

The new type incinerators[9] are basically similar in design to one another (Fig. 1). They follow the established pattern of commercial incinerators where the primary combustion products flow into a secondary chamber where they are passed through an enveloping flame.[1] In most cases, the manufacturers have achieved this dual chamber feature with little or no increase in external size of the incinerator, and with no significant decrease in holding capacity. The burner is normally designed to discharge approximately $^1/_3$ of its Btu output into the primary chamber, and $^2/_3$ directly into the secondary chamber. A single venturi and control system feeds gas to the dual-purpose burner.

The down-draft design of the combustion chamber with its attendant low gas velocities in the secondary chamber is claimed by many manufacturers to produce a settling action which traps out the greatest percentage of the larger particles of fly ash before the products of combustion are discharged to the atmosphere. Our test results and observations substantiate this claim, and the City of Detroit has conditionally approved installation of the new type incinerators without requiring the conventional spark arrester. Field experience will determine whether this waiver is to become permanent.

Test Apparatus

Due to space and financial limitations available to the bureau, the local public

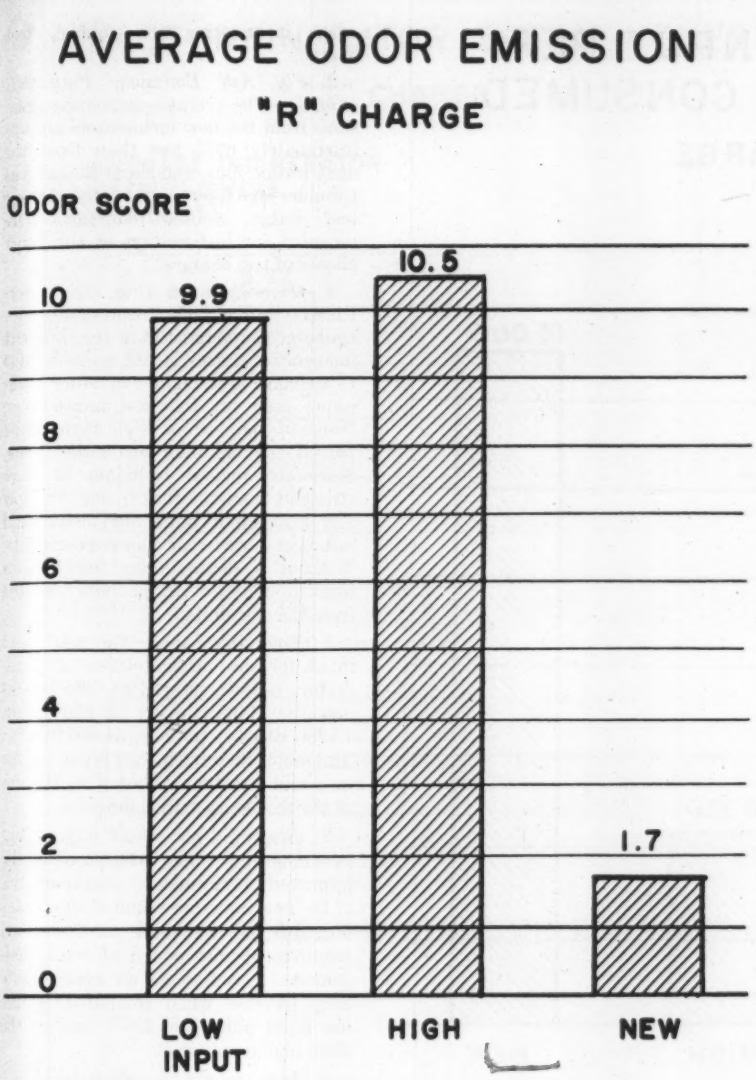


Fig. 5.

utility made available to us sufficient space and equipment to carry forth our evaluation program at their training center. Although the actual tests were accomplished by municipal employees, the gas company did provide us with the services of one of their employees for assistance in setting up and maintaining test equipment. This is yet another example of the gas industry-air pollution control co-operative approach to solve mutual problems.

The schematic layout (Fig. 2) traces the path of the products of combustion through the various test components. The gases are initially discharged into a dilution chamber of approximately 480 cu ft. The front of this room is fitted with two variable area openings to admit outside dilution air in the rate of 15 parts by volume of fresh air to one part of combustion gas. This ratio was selected because it was felt this would simulate field conditions where the products of combustion would travel approximately 15 ft before entering a possible adjacent open window. It was calculated that a gas stream moving this distance would entrain sufficient surrounding air to dilute itself to 15 to 1. The room is evacuated by a draft-inducing fan. The diluted gases are then discharged horizontally to the atmosphere at a point about six feet above ground level. Appropriate dampers are provided in the fan duct system to establish the required test draft of 0.01 in. water column at the incinerator flue collar.

Sensitive instruments of the continuous recording type are used in the incinerator test room to measure draft and flue gas temperatures. Static draft is measured in the 8 in. x 10 in. chimney stack one foot above the point of entry of the incinerator smoke pipe. The flue gas temperature is taken at the point where the smoke pipe enters the chimney.

The products of combustion from the incinerator travel through a flue rising through the ceiling of the test room. This flue extends sufficiently high to provide adequate access for stack sampling instruments, then makes a U-bend and discharges the combustion gases into the dilution chamber. Near the discharge end of the flue pipe inside the dilution chamber a viewing glass has been inserted to observe the smoke density characteristics of the flue gases.

A platform on the top of the test room ceiling serves as a comfortable site for the stack sampling crew to obtain all the necessary data for determination of the particulate loading of the flue gases. Instruments used in the flue gas sampling are a velometer, pyrometer, suction pump with filter, and an Orsat apparatus.

Test Procedures

The initial test performed on each incinerator is the maximum exit gas temperature test. It is conducted to determine peak flue gas temperatures obtained under accelerated burning and extreme draft conditions. Successive charges of shredded paper are burned until a stabilized condition is obtained. As in all other tests, proper measurements are made to determine flue gas particulate grain loading and exit gas composition simultaneously.

The particulates are collected on a fiber glass filter with a self-developed high volume pump under isokinetic conditions. Integrated flue gas samples are withdrawn from the stack throughout the particulate sampling period at a constant rate by the liquid displacement method. Corrections are made later to reduce the grain loading to standard conditions of 50% excess air and 500°F temperature. The adequacy of this stack sampling procedure is commented on by R. L. Dougherty.[5]

A total of four different test charges, including the AGA simulated garbage load are fired in the incinerator (Appendix II). In all cases duplicate tests for each charge are run for smoke, odor, and fly ash evaluation and the results averaged.

An odor panel of five qualified persons makes periodic odor observations of the effluent gases at the dilution room outlet.[8] These observations are made at one-minute intervals. Prior to these observations, the odor panel members familiarize themselves with the odor from the burning of two sheets of newspaper in an open container. This is the reference odor and is compared to the odor in the discharged gases. Con-

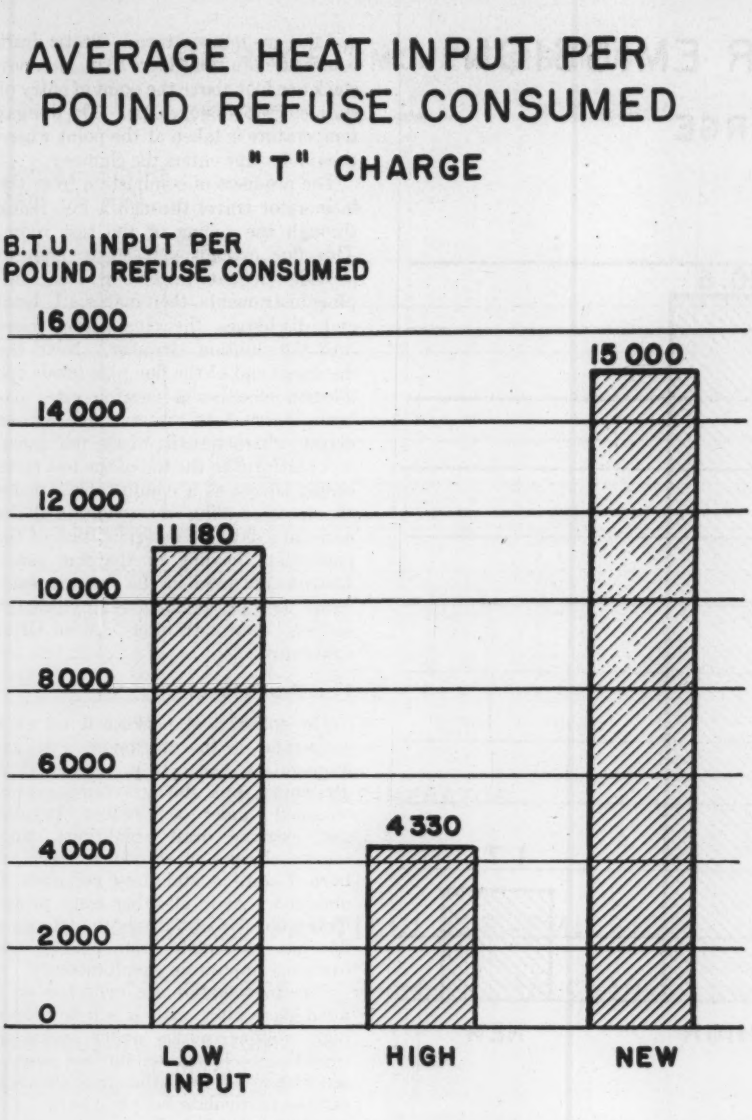


Fig. 6.

currently with odor observations, a trained observer is stationed in such a position as to view the smoke emitted from the incinerator through a glass panel inserted in the chimney. He records the density of the smoke in equivalent Ringelmann numbers at $^1/_2$-min intervals. A scoring system is again used to reflect whether or not the incinerator smoke emission performance is acceptable.

Test Results

The Bureau has tested 35 different model incinerators since the inception of the test program. Twenty-three of these were submitted for evaluation under our new regulations and 10 have fully passed our requirements. However, three of those rejected by our test procedures passed present AGA test requirements. This conflict will be taken up in greater detail in a later portion of this paper.

A comparative listing of the data obtained from testing 23 domestic incinerators is included in Appendix III. A summary of the results for the more pertinent data is as follows:

1 Smoke Emission (*Fig. 3*)—There is a substantial reduction in the smoke liberated from the new incinerators. The results clearly show that the dehydrating (low input) unit was a true smoke generating apparatus when burning the garbage test charge. However, it can also be noted that the low input unit was a relatively good performer when incinerating the rubbish test charge.

2 Fly Ash Emission, Particulate (*Fig. 4*)—The average particulate emissions from the new incinerators are approximately 69% less than from the dehydration unit, and about the same as the older high input units for the garbage test charge. Similar reductions were recorded for incineration of the other classes of test charges.

3 Odor Emission (*Fig. 5*)—Unfortunately, direct comparison of the odor emission characteristics of the different incinerator classes is not possible, due to a change in the odor evaluation technique used for the new incinerators. None of the low or high input units passed the old odor evaluation tests. Since the revised technique is more stringent than the former one, the low and high input units obviously could not meet our current odor requirements. Without a doubt, there has been a marked decrease in the odor emitted from the new units.

4 Total Btu Input—The total heat input for the various classes of incinerators tested averaged as follows: (*a*) low input, 1400 Btu/hr; (*b*) high input, 15,700 Btu/hr; (*c*) new, 34,900 Btu/hr. The major increase in Btu input for the new unit can be attributed to the use of the secondary burner principle.

5 Btu Input per Pound Refuse Consumed (*Fig. 6*)—The attainment of the improved performance characteristics of the new units has required significant increases in the total auxiliary fuel requirements per pound of waste consumed. It represents an approximate 25% increase when compared to the low input units, and 225% against the older high input units.

6 Incinerator Effectiveness (*Fig. 7*)—The incinerator effectiveness represents the percent by weight of the charge which remains as a residue after completion of the incineration period. The low input units apparently did a more efficient job of dehydration than incineration, as can be seen by their poor performance in this test.

Although the new units require a higher total heat input than the older high input units, the amount of thermal energy directed to the primary chamber is approximately 25% less. This reduction apparently has not adversely affected incinerator effectiveness, as compared to the old high input models.

7 Peak Flue Gas Temperature (*Fig. 8*)—Although the new units have a substantially higher thermal input, the average peak flue gas temperatures (after barometric damper) are surprisingly less. This is accomplished by restricting the quantity of combustion air admitted to the primary chamber which causes a "slowdown" in the refuse combustion rate.

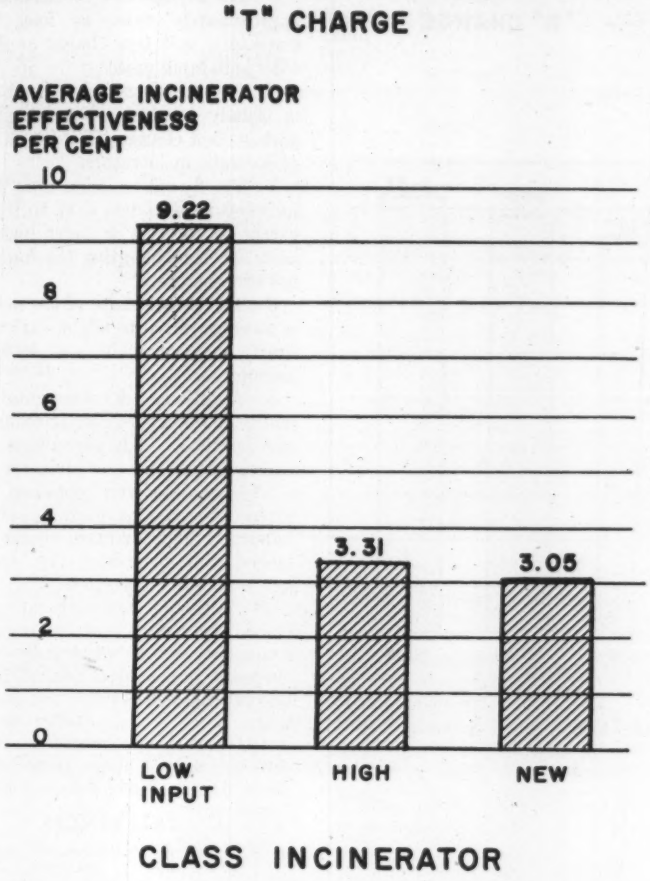


Fig. 7.

Future Aims

The success of this program can be attested to by the excellent field performance experienced over the past two summers, when one would expect nuisance conditions to occur. Although several hundred complaints have been registered to the bureau over the past two years against the operation of domestic incinerators, only three were a result of operation of the new approved models. In two of these cases, the home owner was not using the gas burner; in the other case, the burner was defective.

These latter two findings however point up a very important inherent weakness in any waste disposal program geared on the use of domestic incinerators. If the gas burners are not used and the equipment is not kept in good repair, then a large scale public nuisance situation can only result. It is considered impractical from an air pollution control agency standpoint to rely upon punitive enforcement procedures to solve any such deteriorating condition. The true success of any such program depends entirely upon the co-operation of the home owner in properly using and maintaining his equipment.

In any event, our limited success does not mean that we will suspend our interest in domestic incinerators. We, and the gas industry, are presently aware of some product improvements which would be desirable from an air pollution control and/or consumer appeal standpoint. It is our intention to meet again with gas industry representatives so we may review the present status of past efforts and modify our regulations so the desired improvements can be made available to the public. The following potential modifications in incinerator design and/or performance deserve some investigation:

1. General improvement in smoke, odor, and fly ash emission.
2. Reduction in total required burning time per waste charge.
3. Reduction in total required Btu input per waste charge.
4. Reduction in percent of unburned waste in residue.
5. Improvement in the life of the materials of construction.
6. Elimination of the barometric damper in the breeching and relocating it as an integral part of the incinerator to facilitate installation and to prevent variations in field settings.
7. Redesign of incinerator to permit burning of dry waste materials without depending upon high Btu auxiliary heat.
8. Redesign of incinerator to permit back-draft free service on low draft conditions.
9. Reduction in breeching and exterior casing surface temperatures.
10. Development of fool-proof timer mechanism to prevent shutting off of main gas supply before minimum time established for effective incineration.
11. Development of more effective techniques for removal of ash to reduce difficulty in fouling of pilots and ignition of main charge.

Detroit vs Present AGA Test Procedures

To our knowledge, the Detroit regulations and test procedures spelled out for the first time in simple terms the extent of emissions from domestic incinerators which would be permissible, and how these emissions were to be evaluated. Subsequent to, and possibly as a result of the passage of our regulations, the AGA undertook a review of their long-standing requirements and modified their regulations to include many of the provisions in Detroit's test procedures.[2]

Unfortunately, there still remain several differences in Detroit's regulations and present AGA requirements which are sufficiently important to prevent us from adopting the AGA regulation as the sole basis for approval in Detroit. We feel that the AGA test "hook-up" does not reflect the actual field conditions imposed upon the units, and the smoke and odor requirements do not impose sufficient restrictive performance criteria to yield nuisance-free incinerators. Of the 11 units which were tested and approved by AGA, three have not passed our performance requirements—all by very wide margins. From a practical consideration, Detroit would prefer to accept AGA requirements as a basis of approval, but in view of the foregoing, cannot compromise its acceptance. It is our earnest desire to co-operate with AGA so that we may ultimately develop mutually acceptable requirements which would enable us to suspend our time-consuming and costly test activities.

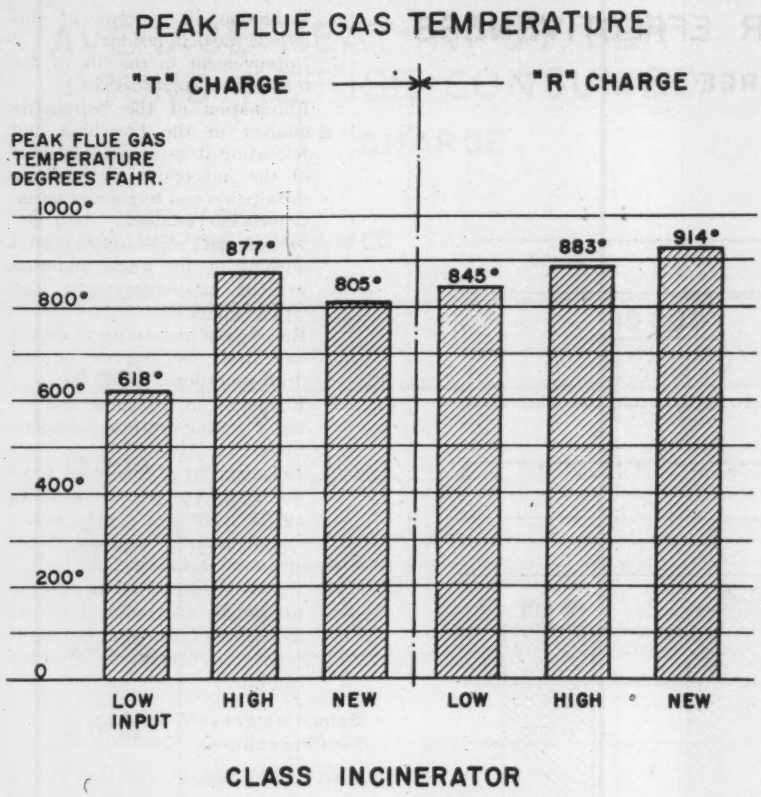


Fig. 8.

In view of the past actions by AGA, we have no doubt that such a goal can be achieved.

Conclusions and Recommendations

1 The performance characteristics of the new incinerators are significantly better than the dehydrating (low input) or older high input incinerators from a smoke, odor, and fly ash emission standpoint.

2 The odor evaluation test appears to be the most difficult requirement to pass.

3 The odor performance characteristics follow the same trend as the smoke emission characteristics; however, the smoke performance could not in itself accurately represent the odor performance characteristics.

4 The average new incinerator requires approximately 35% more heat input per pound waste consumed than the low input units, and 250% more than the older high input units.

5 The average new incinerator takes approximately twice as long to incinerate a unit test charge as did the older high input unit.

6 The fly ash emission (particulate) is usually greatest when burning the garbage test charge ("T") for all classes of domestic incinerators.

7 The fly ash emission from the new incinerators does not vary to the same extent as the low or older high input units when incinerating the four different test charges.

8 The performance of the new units is more sensitive to slight variations in draft, operating skill, and installation techniques.

9 Additional developmental effort will be necessary to permit reduction in the relatively high percentage of CO emissions from the new incinerators.

10 No data were obtained on the extent of emissions, such as aldehydes, unburned hydrocarbons, oxides of nitrogen, sulfur dioxides, etc., from the new domestic incinerators.

11 Although test data are not included in this report, a preliminary evaluation of one electrically-fired incinerator indicated a general performance about on par with the low input units.

12 Future developments should be directed toward those items noted in the section entitled "Future Aims."

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Appendix II—Performance Results of Domestic Incinerators "T" Charge (Garbage)

Type Unit	Incinerator	Capacity, Bu	Total Btu Input per Hour	Hours Operation	Btu Input per Pound Refuse Consumed	Smoke Score for 60 Min	Particulate Grains/Cu Ft Corrected	Odor Score	Combustion Air, Actual/Theoretical	Dry Flue Gas Analysis % by Volume CO	CO_2	O_2	Peak Flue Gas Temperature, °F	Incinerator Effectiveness, %
Low input	A	1.5	2,000	—	—	53.5	—	—	—	—	—	—	—	—
	B	1.5	2,000	96	14,250	—	0.110	—	7.70	0.30	2.0	18.4	835	19.06
	C	1.3	1,700	96	10,600	63.0	0.304	—	7.50	0.06	0.80	18.8	510	7.20
	D	1.8	1,500	96	8,700	38.0	0.107	—	6.49	0.30	2.45	17.9	505	1.40
High input	E	1.8	20,000	6	7,300	12.5	0.0266	10	4.19	0.75	3.75	16.30	1280	1.10
	F	1.5	10,000	—	—	27.5	0.1120	—	5.13	0.60	2.45	17.55	380	—
	G	1.5	20,000	—	—	58.0	0.4850	—	5.88	0.75	2.50	17.70	470	—
	H	1.5	20,000	4.5	5,580	26.5	0.3750	—	4.65	0.55	3.25	16.75	735	1.90
	J	1.7	10,000	3.5	3,800	54.5	0.0200	—	5.53	0.65	2.10	17.65	710	7.65
	K	1.5	12,000	—	—	7.5	0.0550	—	4.12	0.55	3.75	16.15	1270	3.40
	L	1.5	10,000	3.1	1,850	—	0.0660	—	6.90	0.30	1.65	18.20	1330	2.50
	M	1.5	20,000	3	3,720	6.5	0.056	—	6.93	0.30	2.25	18.10	920	3.22
	N	1.5	20,000	3	3,750	12.5	0.089	—	5.40	0.65	2.85	17.35	800	3.40
New improved	O	1.6	38,000	6	14,500	15	0.055	5	4.02	0.55	3.4	15.9	620	6.8
	P	1.5	30,000	6	11,200	7	0.101	6	5.72	0.28	2.5	17.5	660	2.16
	Q	1.5	30,000	6	11,300	2	0.012	0	4.39	0.15	2.55	16.6	670	4.1
	R	2.0	35,000	9	19,800	9.5	0.083	4	5.20	0.35	2.45	17.25	620	0.86
	S	1.5	35,000	6	13,200	2.0	0.0118	0	4.4	0.225	2.80	16.6	985	4.55
	T	1.5	35,000	6.35	14,250	0	0.157	3	4.48	0.35	3.0	16.60	860	2.5
	U	1.5	38,000	7.5	17,100	2	0.050	6	2.82	0.60	5.05	14.00	980	1.70
	V	1.6	35,000	7.75	22,700	0	0.105	0	3.89	0.25	3.35	15.95	650	5.30
	W	1.5	35,000	6.5	13,900	0	0.027	2	2.90	0.30	5.0	13.85	1160	1.70
	X	1.5	38,000	5.5	12,500	0	0.008	0	3.03	0.10	4.80	14.30	840	0.90

Appendix III—Performance Results of Domestic Incinerators "R" Charge (Rubbish)

Type Unit	Incinerator	Capacity, Bu	Smoke Score for 60 Min	Particulate Emission, Grains/Cu Ft Corrected	Odor Score	Combustion Air, Actual/Theoretical	Dry Flue Gas Analysis, % by Volume CO	CO_2	O_2	Peak Flue Gas Temperature, F
Low input	A	—	—	—	—	—	—	—	—	—
	B	1.5	8.0	0.027	6	5.09	0.05	3.35	16.95	1100
	C	1.3								
	D	1.8	14.5	0.107	12	6.55	0.15	2.15	17.95	590
High input	E	1.8								
	F	1.5								
	G	1.5	59.5	0.330	13.0	5.8	0.90	2.35	17.75	600
	H	1.5	31.5	0.586	14.0	4.42	0.75	3.40	16.60	550
	J	1.7	10.5	0.048	—	4.80	0.40	3.25	16.85	—
	K	1.5	6.50	0.049	—	3.90	0.33	4.0	15.75	1020
	L	1.5	13.0	0.018	—	3.97	0.10	3.35	16.00	1230
	M	1.5	7.50	0.045	9	3.17	0.23	5.6	14.45	1140
	N	1.5	11.50	0.056	6	4.1	0.23	4.05	16.05	760
New improved	O	1.6	10	0.075	4	3.13	0.50	4.95	14.40	700
	P	1.5	7.5	0.028	2	5.30	0.30	3.00	17.20	700
	Q	1.5	11	0.018	4	3.54	0.45	3.60	15.55	920
	R	2.0	2	0.033	1	4.21	0.75	3.40	16.40	720
	S	1.5	12	0.0179	3	3.33	0.30	4.40	15.0	1020
	T	1.5	0	0.052	0	4.49	0.20	2.95	16.60	800
	U	1.5	0.5	0.036	3	2.26	0.30	7.00	12.05	250
	V	1.6	0	0.090	0	4.2	0.33	2.75	16.2	680
	W	1.5	0	0.010	0	2.53	0.25	5.90	12.95	1180
	X	1.5	0	0.008	0	1.95	0.53	8.55	10.60	1180

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Appendix I

Smoke Scoring Technique

For each charge tested a score will be computed as follows: smoke of No. 1 or less density is disregarded. The total minutes of No. 2 smoke will be multiplied by two, the total minutes of No. 3 smoke will be multiplied by three, etc. The sum of these products is the smoke score for this test. If in any period of 30 consecutive minutes this score exceeds eight, the incinerator is considered to have failed this test. The score of eight is the equivalent of four minutes of No. 2 Ringelmann, which is the maximum permitted by the regulations.

Odor Evaluation Technique

An odor panel of five qualified department personnel (excluding Bureau of Air Pollution Control employees) makes periodic observations of the effluent gases at the mixing room outlet. Prior to these observations, the panel members familiarize themselves with the odor produced by the burning of two sheets of newspaper in an open fire.

The first observations are made at the time smoke first appears at the mixing room outlet or at a signal from the operator inside the building that combustion gases are entering the mixing room. Observations are made by the various panel members at approximately the same time.

The observations are made at not less than one-minute intervals, continuing until it is certain that the odor-producing portion of the burning cycle is finished.

The following degrees of comparative odor intensity may be selected by the panel members. For purposes of scoring, numerical values are assigned as noted:

a Much more objectionable than the reference odor—1
b More objectionable than the reference odor—2
c Same as the reference odor—3
d Less objectionable than the reference odor—4

The sum obtained by adding the values reported by each panel member for a given observation is the score for that observation. For example, in a typical test, three of the five panel members marked on their data sheets that the odor was "more objectionable," one member recorded the odor as "the same," and one member felt the odor to be "less objectionable." Using the values noted above, this gives a score of 13 for this particular observation.

If all five observers were to report the odor as being "the same," the score would be 15, the minimum acceptable figure. Any combination of values which totals 15 or more is also considered acceptable. No more than three "failures" (i.e., scores of less than 15) are acceptable in any 15-min period. However, since two separate tests are conducted for each type of charge, an average of failures for the two tests is utilized. For example, the unit may have four failures on one test and two failures on the next test and still be acceptable, since this averages three failures.

PROCEEDINGS of 1960 ANNUAL MEETING

AVAILABLE Through HEADQUARTERS

An EVALUATION of the AEROMETRIC PROBE*

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Disadvantages and limitations of conventional methods to probe the first few thousand feet of the atmosphere and the recent availability of a variety of relatively inexpensive radio control devices have brought about the development of a radio-controlled drone for meteorological and air quality observations.

The drone, with 10-ft wing span, is launched from an eight-foot single-rail catapult as shown in Fig. 1. The flying speed of the drone is 20–25 mph. Its slow speed and maneuverability allow it to be easily positioned where desired. Because of its small size, it creates less disturbance of the atmospheric conditions being observed than would a full-sized aircraft. With the model airplane radio control transmitter it may be dependably operated within a range of ½ mi.

A scale drawing is shown in Fig. 2, and physical data are given below:

Aerometric Drone

Weight.....25 pounds
Propulsion....Single cylinder, two-cycle, 1.2 horsepower glow-type internal combustion engine of 0.60 cubic inch displacement converted to a pusher. This engine delivers 0.70 effective horsepower at 10,000 rpm.
Propeller.....14 in. wooden (#14/6)

Wing

Span.....120 in.
Chord.....20.5 in.
Airfoil section.....11.7% Clark Y
Dihedral.....5°

Horizontal Tail

Span.....50 in.
Chord.....12.5 in.
Airfoil section.....8% Clark Y

Vertical Tail

Span.....15 in.

Fuselage

Length.....84 in.
Width (greatest).....5.5 in.
Height (greatest).....14 in.

Original construction was fiberglas over balsa. However, because fiberglas is difficult to repair, newest construction of wings and tail assembly is doped nylon fabric over balsa and other light woods. The fuel system is pressurized and a float-type carburetor is used. The rate that fuel is delivered is constant in normal flying operations. The tank holds approximately one pint, permitting 20 minute flight at moderate power setting. Commercial model airplane fuels are used. These contain castor oil for lubrication.

Transmitter and receiver may operate on any one of the five "license-free" radio control frequencies in the 27 megacycle range. Guidance is provided by an eight-channel system wired as follows:

1 Up elevator
2 Down elevator
3 Right rudder
4 Left rudder
5 High motor speed
6 Low motor speed
7 Motor shut off
8 Instrumentation control

One of eight metal resonant reeds mounted over an electromagnet in the receiver vibrates to each audio tone from the transmitter, thereby causing a sensitive relay to close and permitting current to flow to a particular electric control servo.

Two servos operate the rudder and elevator, and another the motor speed device. These produce a push-pull force of four pounds. Power is supplied to the receiver and servos by 15-volt hearing aid batteries and by a combination of two 2.4-volt rechargeable nickel-cadmium batteries.

The prototype drone was designed and built by Temco† Aircraft Corporation, Dallas, Texas, from specifications supplied by us. The aircraft is inherently aerodynamically stable and not difficult to pilot, but prior experience at the controls of a full-sized aircraft is helpful in learning to fly it. Launchings and landings are made virtually "hands off." Some "up" elevator is used when launching in calm, and the drone must be kept headed into the wind when landing, otherwise no control is required for these maneuvers. During flight, trim is maintained by setting the motor speed control. Because of its stability there is no need for ailerons or gyros, as have been used in some military drones.

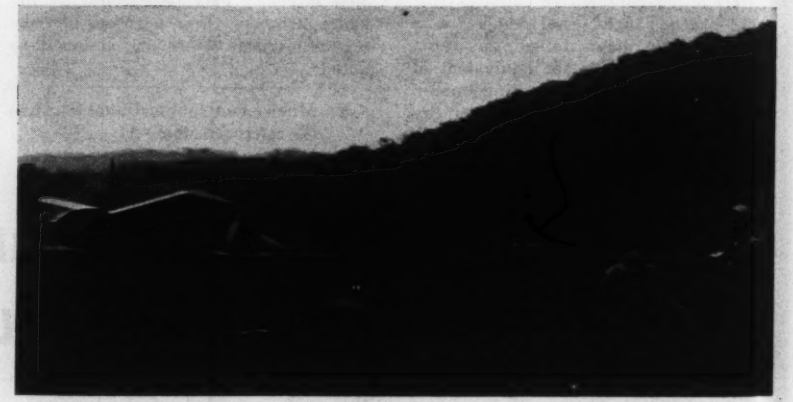
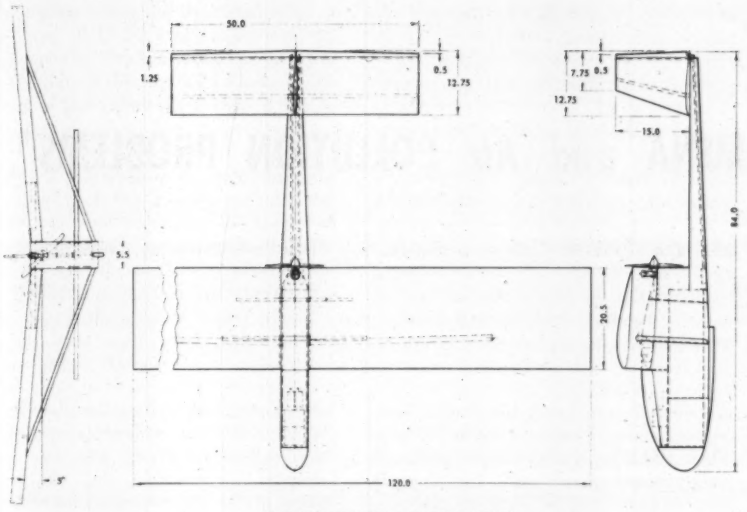


Fig. 1.

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

† Mention of any specific commercial products does not imply in any way endorsement of these products or recommendation of them over similar commercial products.



RADIO CONTROLLED AIR SAMPLING AIRPLANE

Fig. 2.

The basic design is that of a powered glider and the drone has actually been made to soar on thermals with motor off until the flight was deliberately terminated. It can be climbed for the entire duration of the fuel run and then glided down if that type of sounding operation is desired. With the catapult for launching and only a skid for a landing gear, a level, smooth field is not required for operations.

For safety, loss of radio control starts the rotation of a cam in the airplane which, if not reset by the return of the control signal, will stop the motor after about 11 seconds and then release a 14-foot diameter parachute.

By far the most difficult part of the developmental effort has been the design of this "fail safe" device. A number of triggering methods were tried and rejected. The present method operates when the unrectified, and otherwise unused, half of the radio frequency carrier wave becomes weak or is lost because of excessive range or an electronic malfunction.

The instrument package is 30 in. × 5 in. × 7 in., and the useful payload is about five pounds. Air for measurements or sampling is brought in through the nose and is exhausted through a hole in front of the propeller. At present in the package is a standard 403 mc radiosonde transmitter, with a motor-driven cycling switch replacing the baroswitch. At successive intervals air temperature from a thermistor and relative humidity from a lithium chloride strip within a double-walled tube projecting from the nose are transmitted to an ordinary radiosonde receiver and recorder. During each cycle a reference signal is also transmitted for calibration purposes.

Air sampling can be accomplished by means of filters, bubblers, or similar devices requiring vacuum. A useful pump has been constructed of a small-size model airplane motor rotated by a miniature electric motor. The telemetering of radioactivity measurements also seems feasible.

Some experiments have been attempted with several types of pressure transducers, but at present the height of the drone must be determined by triangulation, using double-theodolite techniques. It is easy to fly the drone back and forth through an imaginary vertical plane fixed by one theodolite with azimuth mechanism locked, and the necessary computations can be made from only the readings of the other theodolite.

Weather Bureau or military-type radiosonde ground equipment will not be available to all of the potential users of the aerometric drone. Therefore, consideration has been given to other methods of telemetering. The Temco Corporation designed and tested a special digital telemetering system for it and for meteorological stations of a surface network. There are various ways of interpreting and recording the tone signals from the radiosonde transmitter. One improvised system utilizes a radio receiver, tape recorder, audio signal generator, and oscilloscope.

Experience with the present drone suggests that the next one should not duplicate the present model except in general aerodynamic design. The following is a list of improvements which would be incorporated in new specifications:

1 The drone would be of modular design and be broken down into the following components:
   - *a* Wing
   - *b* Tail assembly
   - *c* Tail boom with servos
   - *d* Fuselage compartment with receiver plus battery for controls and receiver
   - *e* Motor support, motor, fuel tank, and motor controls
   - *f* Parachute, "fail - safe," and ejection mechanism
   - *g* Instrument package, with instrument batteries

   In field operations a supply of modules would be maintained, and any which were damaged or which failed to operate would be quickly replaced. Quick acting fasteners would hold modules together, and in a crash, shear-pins would permit wings and tail assembly to come free with a minimum of damage.
2 The fuel tank would be at least doubled in size. It appears feasible to adapt the drone to carry a standard quart-size fuel can, replacing the hand-made fuel tank.
3 The chute would be somewhat larger and there would be an improved ejection mechanism to lessen the possibility of tangling.
4 The control system would utilize 10 or possibly 12 channels.
5 The servo motors and similar sources of possible radio interference would be provided with shielding and suppressors.
6 The various internal components would be made more accessible. Greater use would be made of doors and access ports. Adjustment screws for tuning could then be reached from outside. There should also be receptacles for test plugs and electrical probes.
7 The electronics would be waterproofed against accidental wetting by light rainfall or dew.

Later developments might include lights for night flying, glide spoilers, and other devices to facilitate landing in a small field, and a mechanism for trimming for level flight that will be independent of motor speed.

For field operations an especially equipped vehicle would be desirable. It might have the catapult mounted on top. Inside it should be able to carry at least three drones with interchangeable parts, repair materials, control transmitter, test equipment, ground receivers and recorders for telemetering a 110-volt power source, and a transceiver for voice communication. Provision would also be made for various meteorological or air quality observations needed at the surface.

Throughout the entire history of the program there has been a continuing effort to improve components and insure reliable operation. There are similarities between the preparations for launching the aerometric drone and the count-down for a large missile. At

(*Continued on p. 385*)

Valley WIND PHENOMENA *and Air* POLLUTION PROBLEMS*

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The purpose of this paper is to summarize those aspects of valley wind phenomena which are particularly relevant to air pollution problems. The method of approach is first to discuss specific examples of isolated aspects of a valley wind and then to indicate how each individual aspect may enter into the over-all pollution picture of a community.

Valleys differ enormously with respect to the height of the walls, the slope of the walls, the distance between the ridge lines, the slope of the valley floor, and the length of the valley. A general theory of valley winds is not available at the present writing and the reader is cautioned that although data discussed in this report were obtained from observational studies in about eight valleys, one should be cautious in extrapolating these data to regions whose topographical features differ markedly from the valleys studied. The valleys studied fall into the following range of topography.

Width of valley floor	0.3 to 4 mi
Distance between ridge lines	2 to 8 mi
Length of valley	3 to 30 mi
Height of ridge lines (above valley floor)	800 to 3000 ft
Slope of valley floor	~0 to 0.016

The data discussed in this report were obtained from a fully instrumented micrometeorological tower at a site near Peekskill in the Hudson River Valley, 1955–57, and in a group of valleys in southern Vermont during the summers of 1957 and 1959. The Peekskill site and some of the data obtained there are described in Davidson and Halitsky (1956–57); a description of the Vermont terrain and some of the data obtained there are given by Davidson and Rao (1958), Davidson (1959), Wen Tang (1960), and Rao (1960). A summary of classical German and Austrian investigations of valley winds may be found in Defant (1951); a model investigation of valley winds and a local pollution problem is contained in Hewson and Gill (1944); while summaries of some aspects of valley winds in western U. S. may be found in Buettner and Thyer (1959).

As a frame of reference, we will assume that ground level concentrations for a period of a season or a year can be expressed in a form

$$\bar{c}(r, \theta) = \iint c(r, \mu - \theta, M) \times P(\theta)\, P(M)\, dM\, d\mu \quad (1)$$

where r is the distance downwind from the source, θ is the azimuth bearing from the source, $P(\theta)$ is the climatological frequency distribution of hourly average wind direction, $P(M)$ is the climatological frequency distribution of the various meteorological conditions which are the parameters of the hourly average concentration function, $c(r, \mu - \theta, M)$. For other than inversion conditions the hourly concentration function around an azimuth mean of zero is assumed to follow that of Sutton:

$$c(r, \mu, M) = \frac{Q}{U \sigma_\mu(r) \sigma_z(r)} \exp - \left\{ \frac{\mu^2}{2\sigma_\mu^2} + \frac{h^2(M)}{2\sigma_z^2} \right\} \quad (2)$$

where U is the wind speed, σ is the standard deviation of the hourly mean distribution of pollutant in the cross wind (μ) and vertical (z) directions respectively. h is the effective height of the source taking buoyancy and velocity rise effects into account. In the above expression, σ, U, and h are functions of meteorological conditions M.

During inversion situations, pollutants will not generally descend to the ground, but because of the diurnal fumigations to be expected after sunrise, the position and concentrations within the plume prior to the breakup of the inversion may be an important feature of the local pollution climatology.

It is evident from equation (1) that a discussion of the long time average pollution picture at a given site must take into account the $P(\theta)$ and $P(M)$ distributions as well as the distribution of the diffusion coefficients implicit in the definition of σ_μ and σ_z. It is obvious, for example, that simply because of the channeling effect to be expected in a valley, the $P(\theta)$ distribution is likely to be more peaked in a valley location than in a flat terrain location. We will now investigate each of these items in some detail.

Distribution of $P(\theta)$—nocturnal conditions: The distribution of wind direction is an extremely important element in the pollution climatology of a given area. A Weather Bureau climatological station is usually chosen so that the observations are representative of a wide area surrounding the station. This means that, insofar as possible, topographical disturbances or distortions are avoided when setting up a climatological station. In relatively flat and simple terrain, the climatological data available from this source may usually be extrapolated safely to neighboring areas. This is not the case, however, in well-formed valleys where under certain larger scale weather situations the valley itself tends to set up a local circulation.

To demonstrate the wide differences in wind direction which may be found within a small area in valley country, the horizontal trajectories of balloons released in mid-valley in five different valleys in Vermont at 2 AM on August 7, 1957 are shown in Fig. 1. A circle of radius less than 10 miles would encompass all the release points. For convenience the trajectories are plotted as if they all originated from a common point. In order to give some idea of the height and speed of the system, the height above valley floor and the time after release are identified for several points along each trajectory.

It is clear that the wind direction for the lower part of each trajectory varies from S, SSW, SE, E, and NNE. These directions in every case are parallel to the walls of each of the five valleys and in general are directed from the valley to the plain. This type of wind is called a valley-plain wind and is found to be the rule in most valleys during reasonably

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clear nights when the overhead wind is less than 10 to 20 mph, depending on the degree to which a particular valley is sheltered from the overhead winds. The height of the valley-plain wind depends on the strength of the prevailing flow; when the prevailing flow is weak, the height of the system is approximately the height of the ridge line. As the upper level flow increases, the height of the valley-plain wind decreases and for certain critical velocities, depending on the geometry of the valley, the valley-plain wind will not exist at any height.

How important are these valley-plain winds to the over-all climatological wind distribution? The answer depends on how often the general climatological regime produces conditions favorable for the development of the nocturnal valley-plain wind. In mid-latitude locations the prevailing winds are strongest during winter and least during summer. It follows that the development of a nocturnal valley wind is to be expected more often during summer than winter. By the same reasoning, the development of these winds may be expected to be greater in regions where the prevailing flow is weak and the skies clear (west coast climates) than in east coast climates characterized by stronger prevailing winds and greater cloudiness.

To demonstrate the importance of these winds in the over-all climatology of an east coast mid-latitude location, consider Fig. 2 where is shown the distribution of wind direction during inversion conditions (solid line) and during noninversion conditions (dashed line) for an anemometer located on a ship about 70 feet above the river in the Hudson River valley near Peekskill, New York. The observations are for the period June to October 1956. It should be remarked that this valley is a broad river valley and that at the point of observation the valley axis runs 030–210°. About a mile or so to the north a relatively narrow tributary valley whose axis is also 030–210° empties into the Hudson River and undoubtedly reinforces the tendency for valley wind development in the main valley.

The wind direction distribution for inversion hours exhibits a very sharp and narrow peak centered at about 020–030°, which corresponds to the down valley direction. Over 50% of the time when an inversion is present the wind direction is somewhere between 005 and 045°. It will be noted that the noninversion hour distribution (dashed line) exhibits no such peak. In fact what seems to be happening is that with the development of an inversion there is a tendency for the wind direction to shift to 030° no matter what the wind direction was prior to the inversion.

It is clear that the $P(\theta)$ distribution for inversion hours will show a very sharp peak during the warmer half of the year. The pollution trajectories will be identical even in this broad valley during about 50% of the inversion hours. It follows then that diurnal fumigations when they do occur will occur with monotonous regularity over much the same fixed points on the ground. The very sharp peak in the $P(\theta)$ distribution for inversion hours will result in quite high values of the integral in equation (1) for downwind directions corresponding to the valley-plain axis for those M cases which give rise to diurnal fumigations.

The relative height of the source with respect to the detailed height structure of the valley-wind is of some importance. Figure 3 is an example of the height distribution of the valley-plain wind for three different nights in the same valley. It may be seen that the height of the system is quite variable, and, incidentally, it should be remarked that the profile for July 27 represents the most extreme profile that we have observed.

The total amount of time that a pollutant will be in the valley-plain flow will depend upon the ratio of the height (including any buoyancy and thermal rise) of the source to the height of the ridge line and the distribution of upper-level wind speeds. To give some idea of how the frequency of the valley-plain direction may vary with height, we quote the following figures for observations in the Hudson River valley near Peekskill. For comparison purposes we present similar figures for Brookhaven National Laboratory which is on relatively flat terrain about 100 miles distant. (See Table I.)

There is a clear and marked decrease in the frequency of the valley-plain wind in this shallow valley, but even at 400 feet the frequency of the valley-plain wind is twice that to be expected from

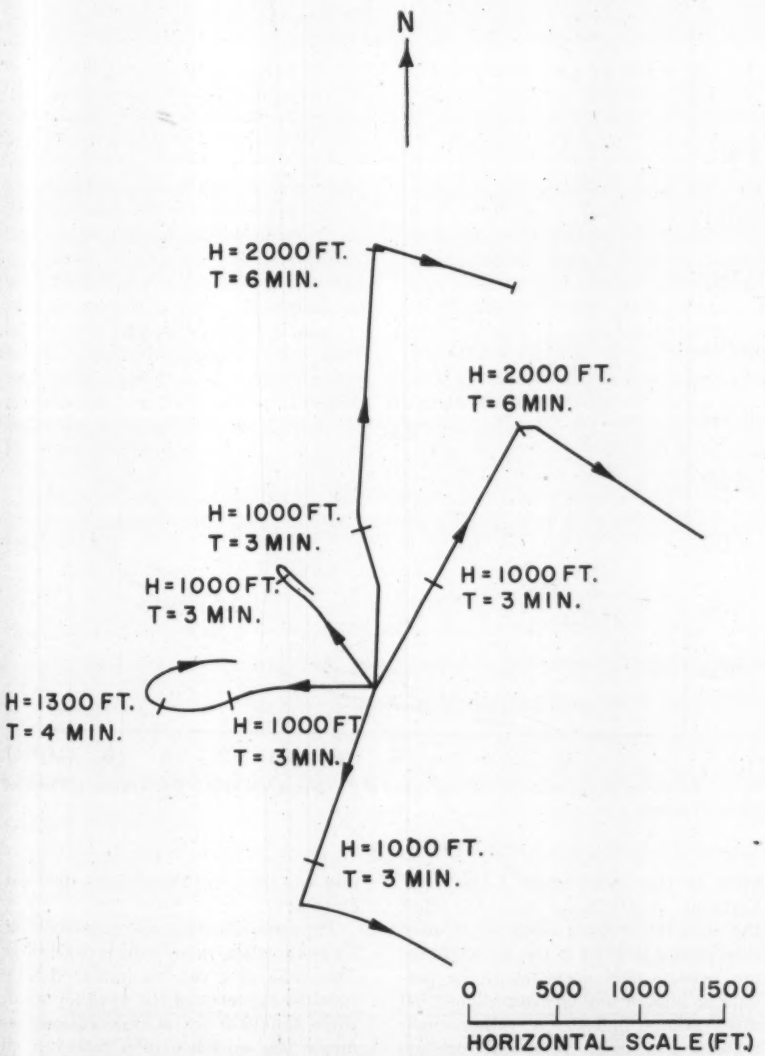

Fig. 1. Horizontal trajectories of balloons released in five different valleys within a 20 mile area at 0200 hrs. Aug. 7, 1957. (h is height of balloon at t minutes after release.)

Table I—Percent of Inversion Hours When Wind Was from 005–045° (Summer Half of Year)

Height (Ft)	Peekskill (1956) (Ht Above Valley Floor)	Brookhaven (1952) (Ht Above Ground)
37	—	7
70	50	—
200	37	—
400	22	11

examination of wind records from relatively flat terrain sites in the general area.

From study of balloons simultaneously released from the sides and floor of two of the Vermont valleys, it appears that with the exception of a thin layer some 100–200 feet thick near the walls of the valley the entire width of the valley is filled with the valley-plain wind. There is surprisingly little gradient across the valley. Near the walls of the valley there is a very shallow layer of air which is moving downslope on both sides of the valley at a speed of about five mph. The maximum velocity shear occurs near the top of the valley-plain system and near the valley sides. Balloons released from the side slopes have a velocity component normal to the slope for 20 to 30 seconds and then proceed in the valley-plain direction with amazing rapidity.

Our observations are simply not detailed enough to say precisely what happens at the corner where the valley side meets the valley floor. Smoke releases on the valley sides halfway up the slope on a few occasions in one of the shallower Vermont valleys suggest that for the most part the smoke travels downslope for a short distance and then seems to accumulate in mid-valley several hundred feet above the valley floor. However, the odor of smoke was detected on the floor of the valley very sporadically. This situation needs to be investigated further. At any rate it appears that a sizable pollution source located on the slopes with any sort of buoyancy and velocity rise would be able to penetrate the shallow downslope system and join the general valley-plain flow.

Distribution of $P(\theta)$—noninversion conditions: The winds we have been discussing thus far are thermodynamic in origin. Classically, the daytime counterpart of this system would consist of a shallow layer of upslope motion adjacent to the valley sides and a wind directed from the plain to the valley in mid-valley. It should be remembered, however, that with the development of thermal instability, the wind regime in the valley may become quite turbulent. Moreover, the development of thermal instability means that the effect of the prevailing wind flow may be in evidence

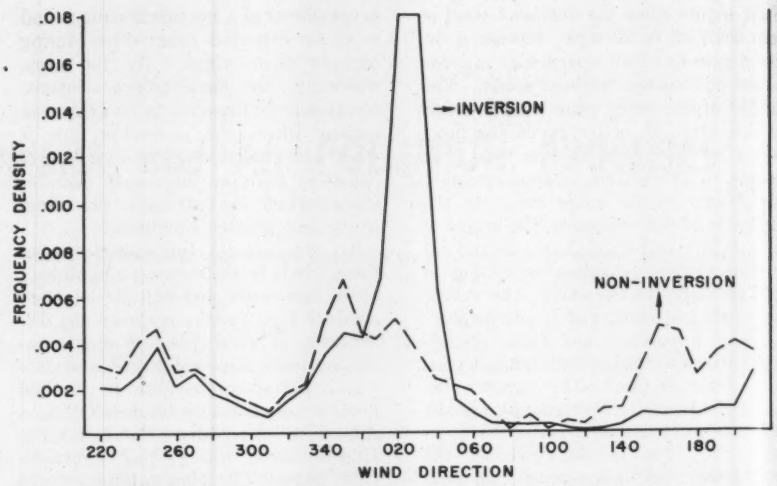

Fig. 2. Frequency density of wind direction for inversion (solid line) and noninversion (dashed line) hours as observed at Peekskill, New York, 70 ft above river, June–October 1956.

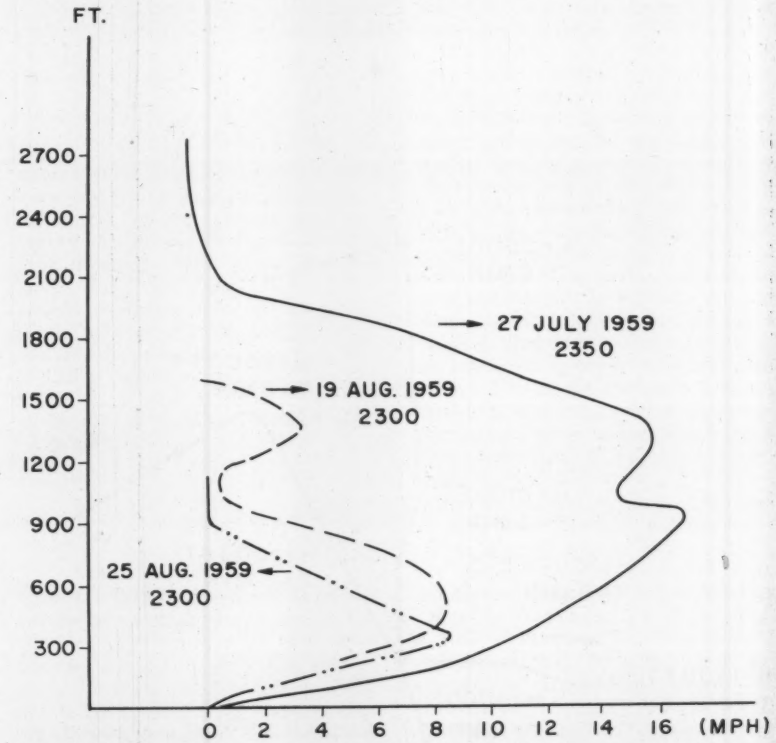

Fig. 3. Illustrating the variation in height and speed of the valley-plain wind. Observations just south of Danby, Vermont.

even at the valley floor. The 1957 Vermont observations indicated that the upslope system along the valley sides begins an hour or two after sunrise but persists only sporadically for perhaps an hour or so thereafter. The 1959 observations indicate a rather more regular and more persistent upslope motion. The chief difference between the two years is that excessive precipitation was noted in 1957 whereas 1959 was quite dry.

The same situation was in evidence as far as the plain-valley wind is concerned. The 1957 observations indicated only sporadic existence of the upvalley wind, while the 1959 set of observations indicate the existence of a rather more sustained upvalley flow, especially in the narrower valleys. A more numer-

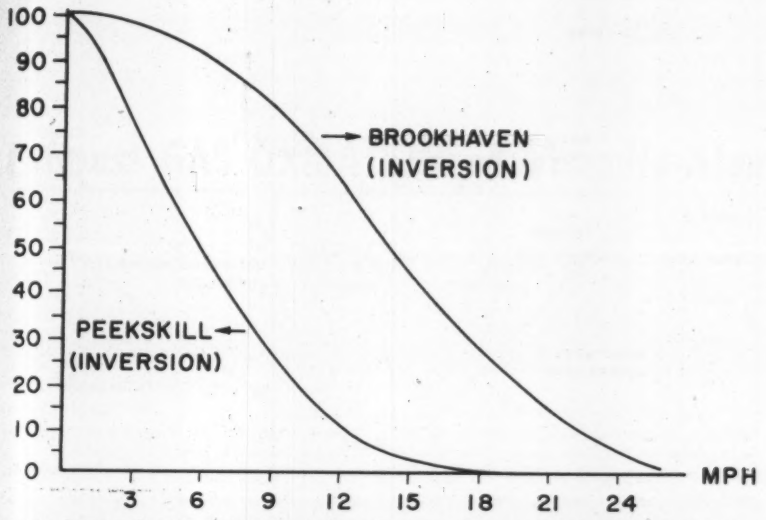

Fig. 4. Percent of total inversion hours during which the wind speed exceeded the indicated values at Brookhaven at 355 ft above terrain, and at Peekskill 400 ft above river and 300 ft above terrain—Brookhaven data for 1951; Peekskill for 1956.

ical evaluation of this aspect of the flow must await further analysis of the 1959 data. It appears then that a dry climate and little overhead wind are quite favorable for the development of the daytime valley winds. For example, Buettner and Thyer (1959) working in a deep valley in the Mt. Rainier region with clear skies and very little overhead wind find good evidence for the existence of the upvalley wind. It should be noted, however, that these winds are fairly turbulent and that the very narrow inversion hour peak demonstrated for the valley-plain direction probably becomes quite broadened for the plain-valley direction.

Distribution of c—wind speed: The variables entering into the determination of c, the average hourly concentration function, include the wind speed and the value of $\sigma_\mu(r)$ and $\sigma_z(r)$ as a function of temperature gradient. The wind speed enters both in the dilution factor Q/U and in determining the effective height of the source $h(U)$. According to Bosanquet, Carey, and Halton (1950) the increment in the height of the source is inversely proportional to U^3. We shall first discuss differences in the wind speed regime between a valley location and an equivalent location in relatively flat country.

For simplicity, consider a station located in mid-valley in a reasonably broad valley. Under inversion conditions this station will more likely than not be under the influence of the valley—plain wind. The maximum wind speed associated with the valley—plain wind varies from valley to valley and from night to night in the same valleys. The average maximum wind speed is on the order of seven to 12 mph. However, because of the sharp-nosed velocity profiles shown in Fig. 3, the average wind speed at pollutant carrying levels may be anywhere from two to 12 mph depending on the effective height of the source, the height of the ridge line, and the strength of the prevailing flow.

With the development of inversion conditions over flat terrain, there is a tendency for the winds at 300 ft, say, to accelerate so that the maximum wind speed at 300 ft occurs during night hours. In valley locations, however, this tendency for acceleration is absent within the valley even during nights when the valley-plain wind does not develop. To demonstrate the difference in inversion climatology, the annual cumulative frequency distribution of wind speed for all inversion hours is shown in Fig. 4 for the 355 ft level at Brookhaven and the 300 ft level (400 ft above river) at Peekskill. It may be seen that the wind speed during inversion conditions is much stronger at Brookhaven than it is at Peekskill. The wind speed was less than six mph at Peekskill for 50% of the inversion hours. By way of contrast, the wind speed during Brookhaven inversion hours was greater than 14 mph for 50% of the inversion hours at Brookhaven. This means that the dilution associated with wind speed will be much less at Peekskill than at Brookhaven. Consequently, the concentrations within the inversion plume will be larger for the valley location as compared with the flat terrain site.

The difference in the wind speed distribution at Brookhaven and Peekskill during noninversion hours is shown in Fig. 5. The valley location exhibits, on the average, less wind speed than does the flat terrain site. The difference is much less extreme than during inversion hours. In interpreting this figure it should be recalled that Bookhaven is subject to a sea-breeze regime during summer hours which may account for some of the difference. On the other hand, the Peekskill site is in a broad valley and the observational site is about two miles away from the upwind ridge line. It is likely that for narrower and better sheltered valleys the daytime valley wind speeds at 300 ft above the valley floor would be substantially less than would be the case for nonvalley locations in the northeastern section of the country. The sole exception would be for locations in valleys whose axes are along the prevailing wind direction and

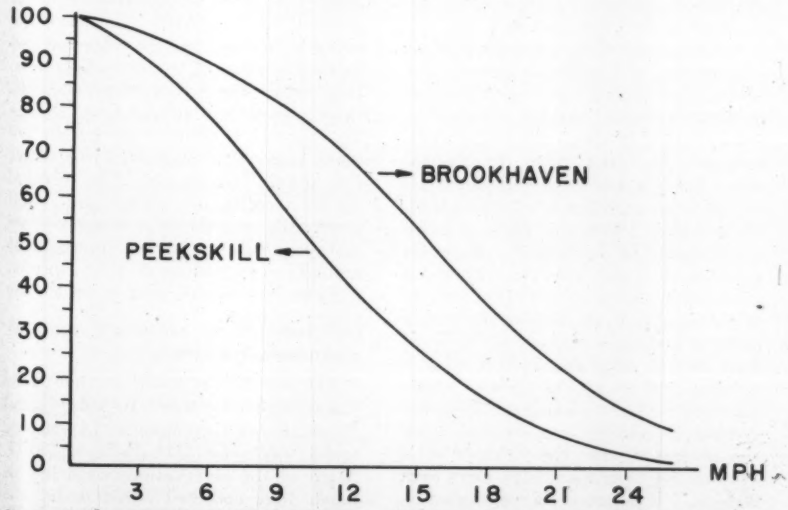

Fig. 5. Percent of total noninversion hours during which the wind speed exceeded the indicated values at Brookhaven and Peekskill. (Same heights and years as for Fig. 4.)

whose walls converge. The so-called Venturi effect then may produce phenomenally high winds.

For other climatological regimes, however, it is possible that the prevailing winds are so weak that the magnitude of the valley wind circulation may be greater than the winds that would have been measured had there been no topographical obstacles. One might expect this to be the case on the west coast of continents in the regions of the subtropical high.

In summary, wind speeds in most valley locations in the zone of the westerlies are less than they would be over flat terrain. It follows that plume dilution associated with the wind speed term in equation (2) would be less in a valley location than over flat ground. On the other hand, the effective height of the source tends to be higher in valley locations precisely because of the decreased mean wind speed. Whether the source height increment is sufficient to overcome the relatively poor dilution due to wind speed depends on the heat content and velocity rise of a particular pollution source, and on the magnitude of the difference in diffusion coefficients between the two types of location being considered.

Distribution of σ_z and σ_μ: The parameters σ_z and σ_μ contain implicitly the diffusion coefficients which, in turn, are functions of thermal stability, and the amount of turbulence engendered at fixed wind speed. Comparison of the number of inversion hours observed at the Peekskill installation with those observed at Brookhaven indicate that inversions exist about 32% of the time at both locations, the maximum frequency of inversion occurring during the summer and fall season. This result is not too surprising since the Peekskill site is in such a broad valley that little obstruction is presented to incoming solar radiation. For valleys which are narrow and high enough to reduce the number of direct sunshine hours, it is to be expected that the number of inversion hours will increase.

The turbulence experienced in a valley varies markedly with position in the valley and with the strength and direction of the prevailing flow. It was found, for example, that under unstable conditions with moderately strong winds normal to the ridge line, the rms azimuth angle fluctuations at the Peekskill installation (about one and one half or 1.5 miles from the ridge line) were approximately 50% greater than that observed at Brookhaven under similar meteorological conditions. This implies that the lateral standard deviation of the one hour time-mean cloud, σ_μ, is about 25 to 50% broader at Peekskill than at Brookhaven. On the other hand, study of the vertical component of turbulence suggests that σ_z at Peekskill is only about 10% greater than at Brookhaven. At the same time a recording anemometer located about 0.6 of a mile from the peak indicated an excessive amount of turbulence near the ground. The azimuth angle fluctuations were extremely violent at this location. Observations of the vertical component of wind for this latter site were not available, but it is reasonable to assume that the vertical component of turbulence was also excessive at this distance from the ridge line.

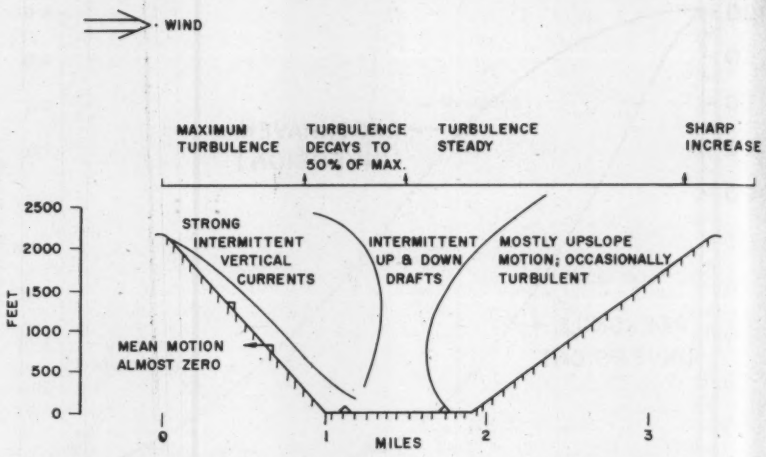

Fig. 6. Schematic sketch of distribution of vertical currents and turbulence with prevailing flow normal to ridge line.

These observations were confirmed in the Vermont series where it was observed that with reasonably strong overhead winds normal to the ridge line under unstable conditions there was a pronounced tendency for rather large scale incursions of winds blowing either up or down the axis of the valley. The up and down valley component of the wind under these circumstances generally average out to zero, leaving a substantial component of motion normal to the slope as the mean motion.

As the upwind slope is approached, all components of turbulence become excessive. A series of simultaneous double theodolite balloon releases at 750 and 1250 ft above the valley floor indicates that the three dimensional mean wind is zero near the slopes although the turbulence is substantial. Some 300 ft above the slope, a mean wind begins to be defined. Superimposed on this mean wind is a very strong field of either up or down motion. Study of the simultaneous motion of the two balloons indicates that an air layer at least 2500 ft deep and 2000 ft wide is moving either up or down simultaneously. The maximum observed downward velocity was 16 mph even though, in this case, the overhead wind at ridge line height was little more than 20 mph. A pollution source located on or near the slope would certainly be spread all over the valley floor in quite high concentrations whenever sustained downward velocities of this order of magnitude are observed.

A rough composite picture of the field of turbulence to be expected in the lee of mountain obstacles is shown in Fig. 6. The figure is based on airplane observations at Peekskill, Lappe, Davidson, and Notess (1959), balloon and tower observations at Peekskill, Davidson, and Halitsky (1957), balloon observation in the Vermont valleys, and wind tunnel simulations described by Strom and Halitsky (1953). The range of prevailing wind speed for the atmospheric observations was 15 to 30 mph. It should be pointed out that this type of eddy wind system is highly intermittent and depends in a complicated way on the strength of the prevailing wind, the thermal stability of the air, and the angle of the wind direction with respect to the ridge line.

In summary, it appears that the magnitude of the diffusion coefficients is sensitive to the relative position of the source with respect to the ridge line and to the direction of the prevailing flow. It is certain that under unstable conditions with winds normal to the ridge line, the lateral diffusion coefficients are much larger than they would be under flat terrain conditions. The vertical diffusion coefficients attain larger and larger values as the slope is approached and quite substantial, but intermittent ground concentrations may be expected from sources located near or on the lee slope of a ridge.

Acknowledgments

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(*Continued on p. 383*)

Exhaust GAS OXIDATION *on Vanadia-Alumina* CATALYSTS*

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Unsaturated hydrocarbons in auto exhaust are believed to be the primary precursors of photochemical smog.[1] Some of the kinetic studies desirable in evaluating catalysts for their oxidation are discussed. Attention is focused on vanadia-alumina compositions because of favorable unsaturate oxidation reported by Cannon and Welling,[2] and because this is a simple system for kinetic study.

Standard Sample

Data on the standard sample used for this work are shown in Fig. 1. This sample was prepared from a low density, high surface area gamma alumina base by multiple impregnation with ammonium metavanadate solution and compares favorably in activity with vanadia catalysts described in the literature.[2, 3]

Primary Variables

The primary variables in exhaust gas oxidation appear to be as shown in Fig. 2.

Catalytic activity is important because it affects the amount of catalyst required. Apart from the smog potential of unsaturated HC's, the reducing components are important because of heat evolved on reaction and because they compete for available oxygen. The adiabatic temperature rise per one percent of CO or H_2 oxidized is 180°F.

The oxygen concentration determines the oxidation state of surface vanadia at fixed reducing gas content and, thereby, may influence its oxidation activity.

Temperature and space velocity are prime variables for all catalytic reactions.

Testing Procedures

Studies of oxidation of pure compounds are easier to reproduce and interpret than exhaust gas data. Therefore, they have been used for fundamental work and for screening catalysts. Studies were carried out at low concentrations of reducing component in air to maintain isothermal excess oxygen conditions using the test unit shown in Fig. 3.

This schematic shows one of four parallel 0.8 in. I.D. tubular reactors which are housed in the same temperature controlled bronze block. Inlet air flows through rotameter *b* control valve 1, catalyst tube, Moore flow controller, and out through the exit rotameter *a*. Reducing gases are added to the air stream through rotameter *c*. Inlet and exit HC content is determined by the flame ionization method, CO by the hopcalite method.[4] H_2 by thermal conductivity and O_2 by magnetic susceptibility. Movable thermocouples connected to a recorder serve to measure catalyst bed temperatures. The techniques used for determining total HC and individual HC's in exhaust have been described in several publications.[5–8]

For exhaust gas studies, valve 2 to the exhaust line is opened, total flow controlled with valve 3, and added air controlled with valve 1.

Test Data on Pure Compounds

Illustrative pure compound data are shown in Fig. 4. These data indicate the typical variation in first order

* Paper presented at the American Institute of Chemical Engineers Meeting, December 1960, Washington, D. C.

Data on V_2O_5-Al_2O_3 Used for Kinetic Studies

Method of Preparation	Impregnation with NH_4VO_3
Avg particle size	0.06 × 0.18 in.
Bulk density	0.65 g/cc
V_2O_5, %	13
Surface area	220 m^2/g
X-ray pattern	Gamma alumina
Crush strength	8 lb

Fig. 1.

Primary Variables in Exhaust Gas Oxidation

1. Catalytic oxidation rate constants of the catalyst
2. Reducing gas content of exhaust gas
3. Oxygen concentration of exhaust gas
4. Temperature
5. Space velocity

Fig. 2.

VEHICULAR EXHAUST TEST UNIT

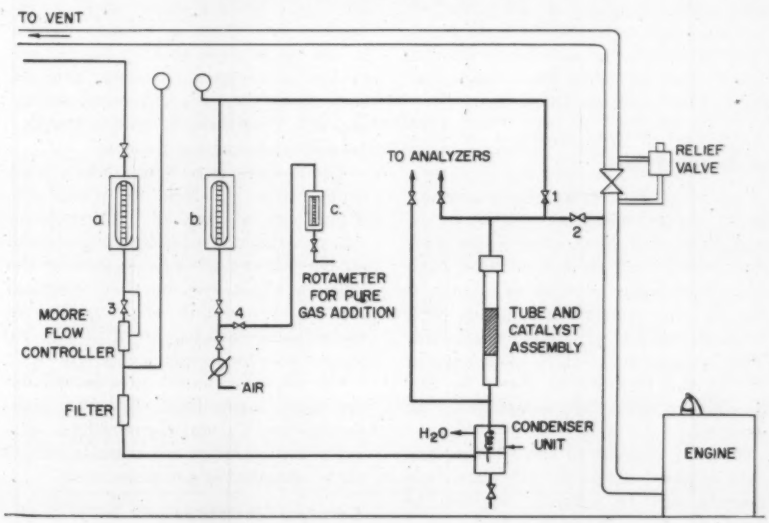

Fig. 3.

Typical Effect of Space Velocity and HC Level on Rate Constant

Ethene Oxidation at 400°C		
SV	Inlet HC	First Order Rate Constant[a]
Min^{-1}	Mol %	Min^{-1}
92	0.42	38
184	0.39	33
366	0.40	40
92	0.48	37
184	0.50	38
366	0.51	28

[a] SV log HC in/HC exit.

Fig. 4.

rate constant found with varying space velocity and HC concentration.

Since variations were random in nature, it appears that the data fit first order kinetics within experimental error as also found by Anderson[9] for methane oxidation on a variety of catalysts.

Figure 5 shows the variation of rate constant with temperature and indicates that the data fit the Arrhenius equation. Activity for olefin oxidation which has an activation energy of 17 K cal is much higher than activity for carbon monoxide oxidation which has an activation energy of 21 K cal/mol. The relative activity agrees with the findings of Cannon and Welling.[2]

The kinetics of H_2 oxidation could not be accurately determined with the unit because oxidation activity of the stainless steel tube was the same order of magnitude as the V_2O_5-Al_2O_3 catalyst.

Although detailed kinetic studies were not carried out on all hydrocarbons, enough work was done at 220 min^{-1} space velocity and 405°C to determine relative activity as shown in Fig. 6.

The data indicate a very marked increase in oxidation rate with carbon number and with degree of unsaturation. For example, in the case of paraffins, oxidation rate constant ranges from below five for methane to 300 for hexane and acetylene has a rate constant of 140 vs 30 for ethene.

Oxidation of Components in Exhaust Gas

A five hp, four cycle 5/1 compression ratio engine operating under idling conditions was used. Gross composition before and after treatment with vanadia-alumina catalyst is shown in Fig. 7. HC conversion is about 60% while H_2 and CO are largely unaffected. The unconverted HC's are largely ethene and methane as shown in Fig. 8. Higher olefins are substantially all oxidized.

It is of interest to see whether the rate constant obtained with pure compounds can be directly applied to exhaust gas. Therefore, "rate constants" obtained with exhaust containing four percent O_2 were compared with those on pure compounds in air as shown in Fig. 9. The agreement for C_1-C_4 HC's is fairly good. This implies that there is enough oxygen in the exhaust gas to keep the surface in the same nearly complete oxidized state as in the pure compound studies and also that there is little interaction between reducing components.

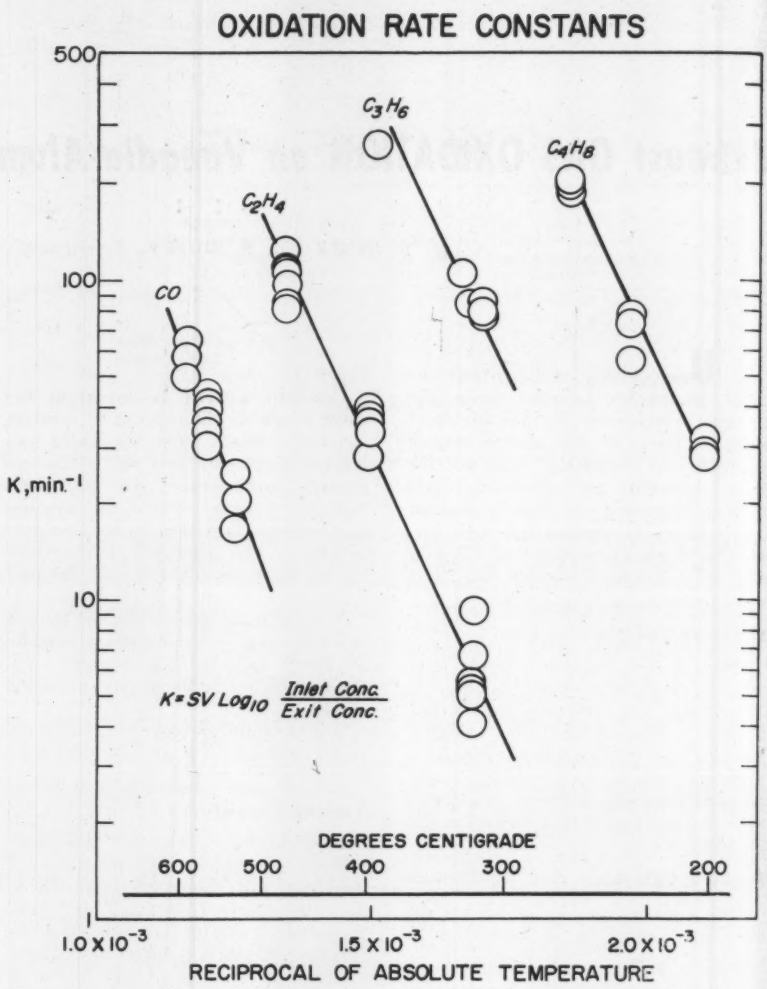

Fig. 5.

These views were borne out in other experiments by lack of appreciable dependence of over-all HC oxidation rate on oxygen level in the range two to six percent and the valence state of the vanadia which was found by chemical analysis to contain the amounts of pentavalent vanadia shown in Fig. 10, at the indicated oxygen levels.

On the other hand, rates in exhaust are much lower than with pure compounds for C_5 and C_6 paraffins. Exactly why exhaust components inhibit their oxidation is not clear.

Catalyst Variables

Numerous vanadia-alumina preparations were tested. As might be expected, the most significant variable found was vanadia content. A direct proportionality between olefin oxidation weight activity and weight percent V_2O_5 was found on catalyst prepared in a variety of ways. This is shown in Fig. 11. Weight activity in cc gas/minute/gram catalyst required for 90% conversion is plotted against weight percent V_2O_5.

Lack of correlation of weight activity of fresh catalysts with particle size and bulk density indicated that diffusion was unimportant under conditions of the tests.

To understand the relationship between surface area and activity, portions of the standard catalyst were heated at various temperatures to give a wide area range and then tested for oxidation activity.

The olefin data are shown in Fig. 12. Ethene oxidation is unaffected by surface area loss down to 70 m^2/gram, but subsequently shows a sharp drop. Propene oxidation activity increases

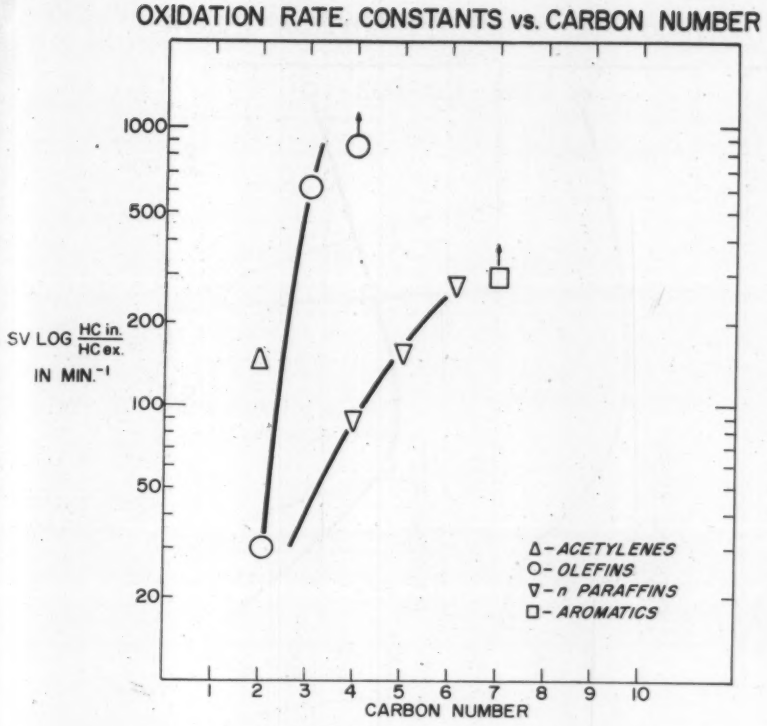

Fig. 6.

Typical Exhaust Gas Composition Before and After Vanadia-Alumina Catalytic Treatment[a]

Component	Mol Percent Before Treatment[b]	Mol Percent After Treatment
N_2	77	78
CO_2	10	11
CO	6.0	5.8
H_2	3.0	2.8
O_2	3.0	2.5
Total HC	0.7	0.3

[a] 400°C, 110 min^{-1} space velocity.
[b] After induction of 10% air.

Fig. 7.

Single Cylinder Exhaust-Nature of HC Before and After Vanadia-Alumina Catalyst Treatment[a]

Component	Percent of Total HC on Carbon Atom Basis[b] Before Treatment	After Treatment
CH_4	20	46
C_2H_4	25	40
C_2H_2	26	0
C_3H_6	11	0
C_4H_{10}		4
C_5H_{12}	4	5
C_4H_8	5	0
C_5H_{10} + C_6H_{14}	4	4
Higher HC's	5	1

[a] See Fig. 7 for Conditions.
[b] Total HC Inlet = 0.70%, Exit = 0.32%.

Fig. 8.

Effect of Oxygen Level on Valence State

Percent O_2 in Exhaust Gas[a]	Percent Vanadium in Pentavalent Form
0.15	23
1.1	53
1.7	73

[a] Idling exhaust from Lauson engine.

Fig. 10.

to a maximum at about 100 m^2/gram and thereafter is about proportional to surface area.

Figure 13 shows oxidation rate constants for both pure paraffins and for paraffins in exhaust. The pure compound data indicate little if any activity decrease down to 100 m^2/gram and thereafter a rough proportionality as found for the olefins. In exhaust, the picture is not as clear-cut.

Summary

An approach is outlined for studying the kinetics of exhaust gas oxidation using data on vanadia-alumina catalyst composition to illustrate the method.

First order kinetics fit available data and the activation energy for the pure olefin oxidation by excess air is about 17 K cal and that for CO is 21 K cal/mol.

Oxidation rate constants in exhaust gas appear about equal to the product of the pure gas constant times the fraction of vanadium in the pentavalent state except for pentane and hexane which are much lower. The rate constant for pure compound oxidation increases markedly with degree of unsaturation and molecular weight.

Activity for oxidation of ethene at 405°C and propene at 325°C directly correlates with V_2O_5 content up to 24%.

On thermal deactivation, oxidation activity normally increases or stays constant down to about 70 m^2/gram and thereafter is proportional to surface area.

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4. W. B. Innes and A. J. Andreatch, Paper in Preparation on Analysis of H_2 and CO in Exhaust Gas.
5. W. B. Innes and A. J. Andreatch

Comparison of Oxidation Rate Constants from Pure Compound Oxidation with Exhaust Oxidation

Compound	Rate Constant = SV Log (HC In/HC Out) 325°C Pure HC in Air	325°C Idling Exhaust 4% O_2	405°C Pure HC in Air	405°C Idling Exhaust 4% O_2
	Min^{-1}	Min^{-1}	Min^{-1}	Min^{-1}
Hydrogen	0	0	<5	<5
Carbon monoxide	0	0	<5	<5
Methane	0	0	<5	<5
Ethene	10	5	30	20
Acetylene	—	27	140	>130
Propene	80	~100	>100	>100
Butanes	—	—	100[a]	110
Pentanes	—	—	130[a]	26
Hexanes	—	—	290[a]	70

[a] Normal compounds.

Fig. 9.

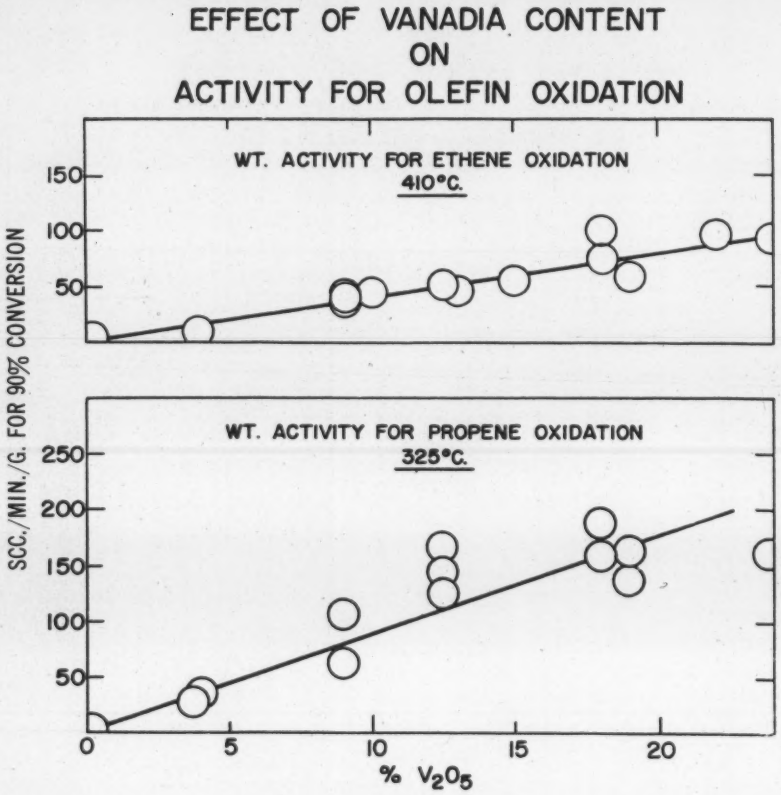

EFFECT OF VANADIA CONTENT
ON
ACTIVITY FOR OLEFIN OXIDATION
WT. ACTIVITY FOR ETHENE OXIDATION
410°C.
WT. ACTIVITY FOR PROPENE OXIDATION
325°C.
SCC./MIN./G. FOR 90% CONVERSION
% V_2O_5

Fig. 11.

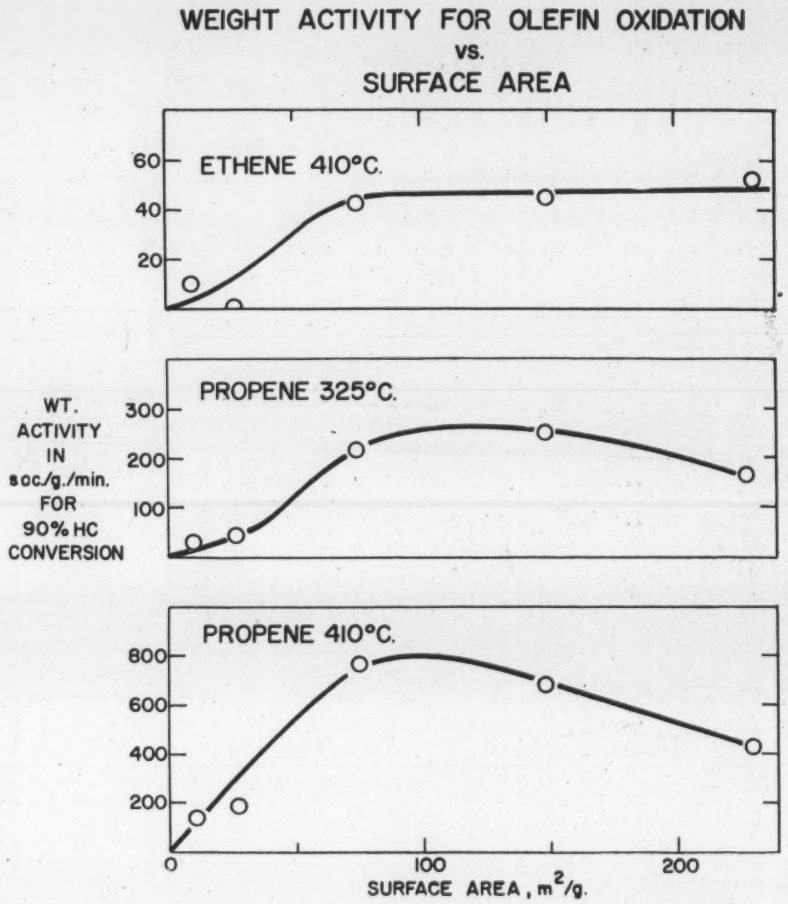

WEIGHT ACTIVITY FOR OLEFIN OXIDATION
VS.
SURFACE AREA
ETHENE 410°C.
PROPENE 325°C.
PROPENE 410°C.
WT. ACTIVITY IN soc./g./min. FOR 90% HC CONVERSION
SURFACE AREA, $m^2/g.$

Fig. 12.

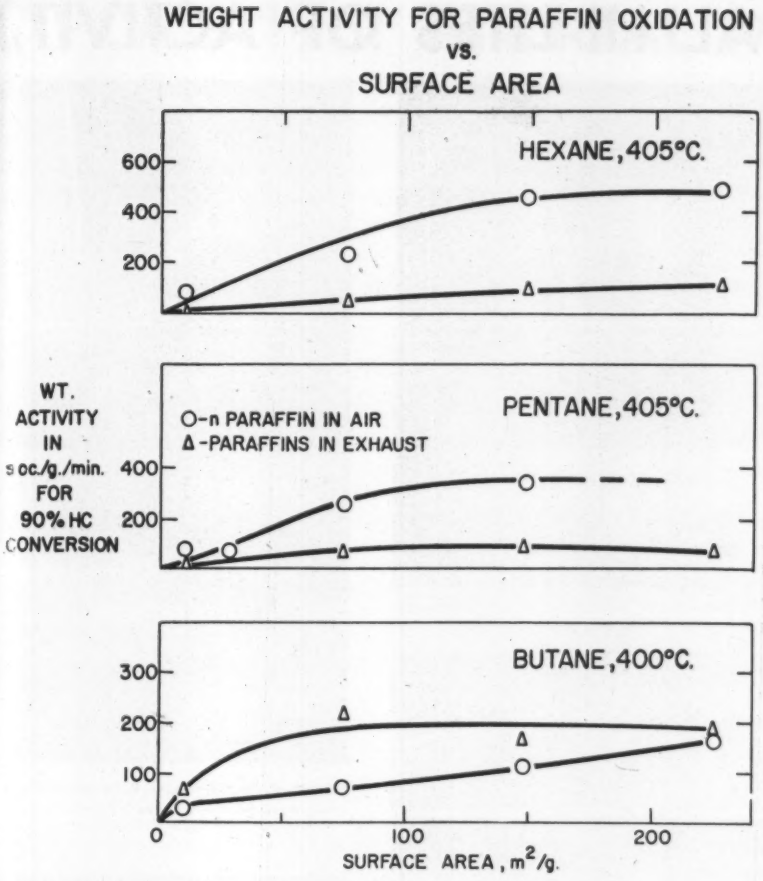


Fig. 13.

Industrial Water and Wastes (November-December 1960).

6. A. J. Andreatch and R. Feinland, *Anal. Chem.*, **32**: 1021 (1960).
7. A. J. Andreatch and W. B. Innes, Instrument Society of America, Preprint No. 46-NY60.
8. R. Feinland, A. J. Andreatch, and D. R. Cotrupe, Paper Submitted to *Anal. Chem.*
9. R. B. Anderson, K. C. Stein, J. J. Feenan, and L. J. E. Hofer, Paper presented at the 138th National Meeting of the American Chemical Society (September 1960).

CALENDAR

August 27–31	Symposium on Weather and Organisms, in conjunction with American Meteorological Society, American Institute of Biological Sciences, Purdue University, Lafayette, Indiana.
September 21–22	East Central Section Annual Technical Meeting, Louisville, Kentucky.
October 4–6	28th Annual Conference of National Society for Clean Air, Brighton, England.
October 16–17	International Conference on Ionization of the Air, The Franklin Institute, Philadelphia, Pennsylvania.
November 27–28	Fourth Conference on Agricultural Meteorology, American Meteorological Society in conjunction with American Society of Agronomy, St. Louis, Missouri.
February 19–21, 1962	Clean Air Conference, sponsored jointly by New South Wales Department of Public Health and University of New South Wales, at the University of New South Wales, Sydney, South Wales.
May 20–24, 1962	55th Annual Meeting of APCA, Chicago-Sheraton Hotel, Chicago, Illinois.

SENATOR NEUBERGER ASKS HELP OF INDUSTRY

The U. S. automobile industry has been asked to help protect the public health by installing "on your own initiative" a device in all new cars which destroys crankcase fumes.

Senator Maurine B. Neuberger (D-Ore) made the request in a recent letter to 14 manufacturers of cars and trucks. She suggested that in the event the automobile industry failed to seize the initiative, it would be "responsible legislation to prohibit the transportation in interstate commerce of vehicles without the protective device."

Senator Neuberger noted that the Automobile Manufacturers Association had rejected a request by the Secretary of Health, Education, and Welfare, that the industry install at the factory a device which destroys crankcase fumes, a factor in air pollution along with auto exhaust fumes. The "blowby" device passes unburned hydrocarbons back into the fuel intake system where they are ignited. To deal with exhaust fumes, California state officials are testing a number of control devices in which chemicals "filter out" harmful fumes.

She said in her letter: "There seems to be good evidence that smog is a health hazard and that the discharge of these raw-gasoline hydrocarbons into the atmosphere helps to produce that smog. Evidently the industry has recognized this by its willingness to include the device for control of these fumes on new cars sold in California."

Installation of the device to control "blowby," according to Senator Neuberger, would be "an opportunity for the automobile industry to take an affirmative step to help safeguard the health of the public." The Senator observed: "If this is not done, I think it would be responsible legislation to prohibit the transportation in interstate commerce of vehicles without the protective device."

SECTION HI-LITES

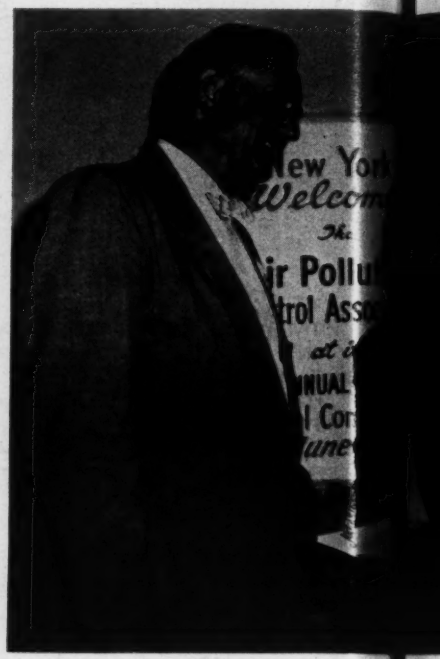
West Coast Section

San Diego hosted its first dinner meeting for the Section August 11; Kenneth Flocke, San Diego's Bureau of Industrial Hygiene Chief, made the arrangements.

Speakers for the occasion were Robert E. Holzer, Professor of Geophysics at UCLA and Professor Albert F. Bush, Sanitary Engineering, also of UCLA. Their topics were, respectively: The Role of Atmospheric Ionization as It Affects Air Pollution; and Electron Microscope Studies of Matter.

PICTORIAL HI-LITES OF ACTIVITIES

LAST MINUTE CHECK—Edward Logelin (*center*) and Charles Gruber (*right*) check on next session with Chairman Ben Linsky. Checks like this kept things running smoothly all through the meeting.

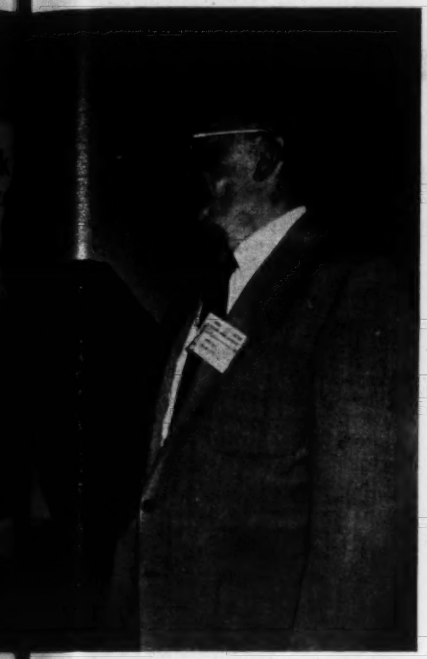


HOW'S IT LOOK?—Harry Ballman (*left*), Arnold An… Harry… These three gentlemen have all held the reins of A… ve sec…

SPEAKERS' TABLES—Speakers and committee members are "camera caught" during the meeting.

GREAT FUN—And "a good time was had by all" … eye v… over 800 who attended this function, which is an o… he meet…

ST APCA'S 1961 ANNUAL MEETING



Harry Pier discuss latest issue of the *APCA Journal*. ...e secretary at Mellon Institute in Pittsburgh, Pa.

FAIR AND SQUARE—Nick Post holds box for TWA hostess as she draws the winning tickets for the lucky recipients. The winners received appliances which were contributed by the exhibitors.

...'s eye view of the president's luncheon. There were ... the meeting.

SMILES FOR ALL—In picture above, President Harry Belyea (*left*) welcomes two APCA members prior to the start of the meeting at the Commodore. Below, D. C. Galloway (*right*) receives APCA Cleaner Air Week Committee Award from Charles Howison, National Chairman of the Committee.

EFFECTS *of High Volatile* FUEL *on* INCINERATOR EFFLUENTS*

ROBERT L. STENBURG, ROBERT P. HANGEBRAUCK, DARRYL J. VON LEHMDEN, and **ANDREW H. ROSE, JR.,** U. S. Public Health Service, Division of Engineering Services, Robert A. Taft Sanitary Engineering Center, Air Pollution Engineering Research, Cincinnati, Ohio

The effects of incinerator design and firing practices on the discharge of atmospheric pollutants from incinerators are being studied in order to establish design and operational standards for minimizing such discharges from industrial and municipal incinerators of the multiple chamber type.

Proper evaluation of the various geometric features of the incinerator requires a thorough knowledge of the effects of different fuels as well as such operational factors as amount and distribution of combustion air, fuel burning rate, amount of fuel per charge, method of charging, and stoking of the burning fuel bed.

Previous studies conducted with a cellulose type fuel have evaluated the effects of operational factors[1] and the effects of fuel moisture content[2] on incinerator emissions. The present study was made to obtain similar data from laboratory combustion tests employing a readily vaporizable solid fuel normally considered as being more difficult to burn than ordinary cellulose material. Together, these completed studies will provide background data for evaluating the effects of changes in incinerator geometry—the next step in this undertaking.

All studies to date have been made in a multiple chamber incinerator having an 8.5 sq ft grate area in a 19.5 cu ft primary combustion chamber, a downpass mixing chamber, and a 16.5 cu ft final combustion chamber. In both the present and past series of tests, comparative effects in terms of stack emissions were measured by making combustion tests at two or more levels of each of the several operational conditions previously mentioned. The test incinerator (Fig. 1) has been previously described in detail in the literature.[1]

Combustion Air

Combustion air was introduced to the incinerator through a system of ducts which permitted accurate control and measurement of all airflow during test conditions. Overfire air entered the front of the ignition chamber at grate level, and swept the surface of the burning fuel bed. Underfire air entered through the ash pit, passing up through the fuel bed. Secondary air passed through a duct in the bridgewall with discharge ports opening into the top of the mixing chamber immediately downstream from the bridgewall throat.

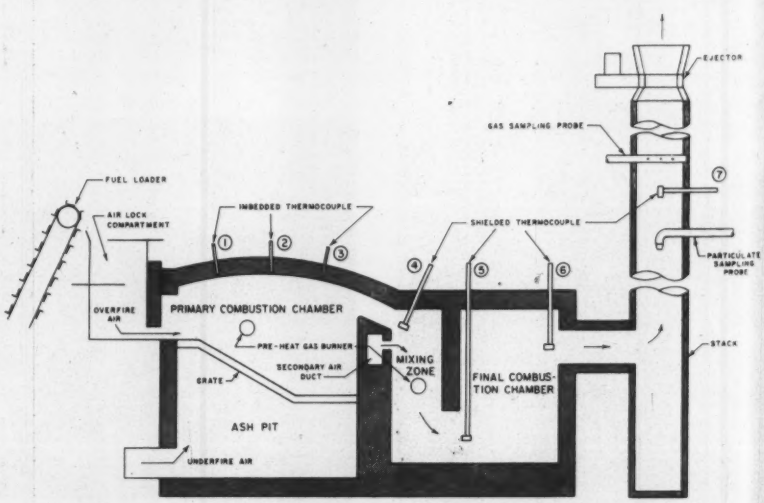
Fuel

Asphalt saturated felt roofing was the high volatile fuel component selected for these tests. Composition of this material was 60% petroleum base asphalt, 37½% felt, and 2½% ash. The felt itself was basically cellulose, being a mixture of rags, paper, and wood fibers. Asphalt roofing material has the characteristic of vaporizing readily at furnace temperatures to produce large quantities of black smoke. Its theoretical combustion air requirement is 135 cu ft/lb while the theoretical air requirement for newspaper is only 68 cu ft/lb.

The fuel mixture used in this series of tests consisted of one part shredded asphalt felt roofing and one part newspaper which had been cut into four inch squares. No moisture was added to the fuel mixture.

Sampling and Instrumentation

The effects of different test conditions were evaluated in terms of the degree to which certain pollutant gases and solids were present in the combustion products discharged from the incinerator stack. Each material of interest was sampled and analyzed using the following techniques and procedures. Continuous measurement of carbon monoxide, carbon dioxide, and total hydrocarbon concentrations was accomplished through the use of nondispersive infrared gas analyzers supplemented with strip chart recorders (Fig. 2). The hydrocarbon analyzer was sensitized with a mixture of benzene, ethylene, and acetylene. Measurement of oxygen was also on a continuous basis using an instrument operating on the paramagnetic properties of oxygen.



SCHEMATIC ELEVATION OF EXPERIMENTAL MULTIPLE CHAMBER INCINERATOR

Fig. 1.

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

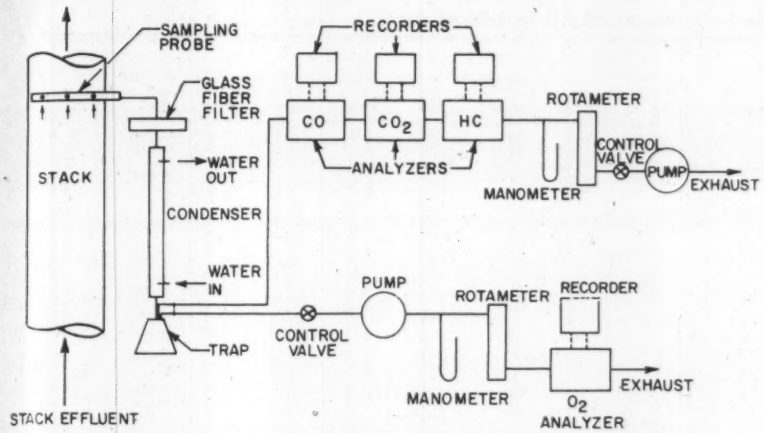


DIAGRAM OF STACK GAS SAMPLING SYSTEM

Fig. 2.

Oxides of nitrogen were measured by the Saltzman modification of the Greiss colorimetric method and expressed as equivalent NO_2. Samples of flue gas for these determinations were collected in evacuated flasks containing the liquid reagent. Each flask was filled with gas by sampling at a uniform flow rate over one or more fuel charging cycles (Fig. 3).

Formaldehyde was measured by a colorimetric technique which involved bubbling a sample of the gas through chromatropic acid.

Particulate loadings were determined by collecting samples on a seven inch diameter glass fiber filter. Samples were taken under isokinetic conditions at a representative velocity point in the stack.

Experiment Design

Five variables were evaluated under conditions designed to produce conclusive evidence as to the effects of a given variable on the discharge of pollutants. These were (*1*) excess air, (*2*) fuel feed rate, (*3*) amount of fuel per charge, (*4*) underfire air, and (*5*) secondary air.

Past experience indicated that simultaneous evaluation of as many as five variables at two levels of testing would be less likely to produce definitive data on the effects of individual variables than tests which would hold a given interacting variable constant while other conditions were varied. Secondary air, underfire air, and amount of fuel per charge required individual evaluations because of interactions of these variables either with each other or with excess air or fuel charging rate.

Basic Conditions

All combinations of the four independent variables shown in Fig. 4 were tested at two levels of each variable to establish a basic set of conditions for this test series. Duplicate tests were made of these and all other conditions evaluated. Use of a constant fuel charging interval of one minute and 48 seconds for the lower level of fuel per charge, required 3 lb and $4^1/_2$ lb per charge for the 100 and 150 lb rates respectively.

In evaluating effects produced by varying the amount of fuel per charge, the ideal comparison would be between "continuous" fuel charging and various levels of "batch" charging. Practical limitations of the experimental equipment rule out "continuous" charging in this study, but charging intervals of less than two minutes provided combustion cycles sufficiently short that they approach a continuous process. To evaluate the so-called "batch" charge, 10 and 15 lb of fuel per charge at six minute intervals provided an adequate contrast with the regularly used 3 and $4^1/_2$ lb charges.

Secondary Air

Secondary air was evaluated under conditions which gave a direct comparison between the use of a portion of the total combustion air when introduced (*1*) as overfire air through the charging door into the primary combustion chamber, or (*2*) through the secondary air ports into the mixing chamber immediately beyond the primary combustion chamber. Conditions tested are shown in Fig. 5.

Underfire Air

In the combinations of conditions shown in Fig. 4, the actual amount of underfire air is a function of both fuel charging rate and excess combustion air. Therefore, in order to separate the effects of underfire air from the other variables, conditions were established whereby (*1*) underfire air was held constant at 72 and 286 scfm for both test levels of excess air

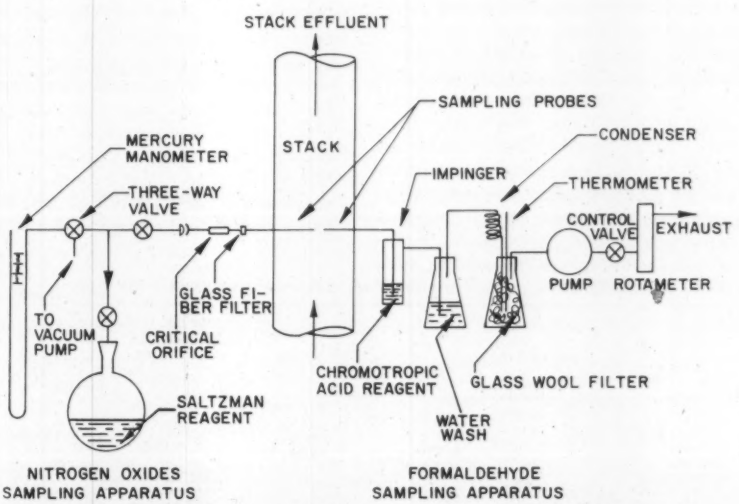


DIAGRAM OF NITROGEN OXIDES AND FORMALDEHYDE SAMPLING APPARATUS

Fig. 3.

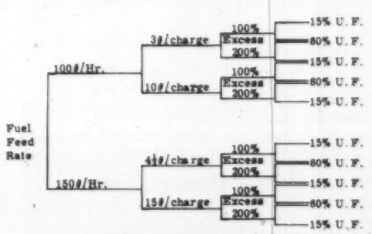


Fig. 4. Basic test conditions.

Table I—Summary of All Test Conditions

Test Conditions															
			Air Distribution												
Excess Combustion Air	Fuel Feed Rate (lb/hr)	Fuel per Charge (lb)	Underfire	Overfire	Secondary	Test No.	Particulate Gr/Scf	Particulate Lb/Ton Fuel	Particulate % Ash	NO_2 Lb/Ton Fuel	CO Lb/Ton Fuel	HC Lb/Ton Fuel	HCHO Lb/Ton Fuel	Average % CO_2
50%	150	4½	80%	20%	0	22	1.31	58.4	5.7	1.8	65.2	3.8	0.008	10.9
		15	80%	20%	0	22-A	1.94	84.0	3.9	2.1	143.5	6.5	0.012	10.1
100%	100	3	15%	85%	0	1	0.09	5.3	20.2	5.2	0.0	0.0	—	9.2
			22½%	77½%	0	9	0.24	14.4	7.9	4.2	7.7	0.7	0.014	7.8
			60%	40%	0	2	0.27	15.6	11.7	4.0	8.9	0.4	—	8.6
			90%	10%	0	10	0.33	19.8	14.2	3.8	17.1	1.3	0.025	8.0
		10	15%	85%	0	25	0.44	19.2	6.7	4.7	27.0	3.4	—	7.7
			60%	40%	0	26	1.11	65.0	7.0	3.3	75.6	13.4	—	8.3
	150	4½	15%	85%	0	5	0.04	2.6	38.4	4.1	0.0	0.0	0.010	8.0
			60%	40%	0	6	0.23	13.3	12.6	4.5	14.6	0.3	0.008	8.9
			60%	15%	25%	23-S	0.25	14.4	9.4	3.6	12.1	0.3	0.006	8.7
		15	15%	85%	0%	55	0.09	5.9	18.5	3.8	0.7	0.6	0.006	8.5
			60%	40%	0	51	0.59	34.0	7.8	3.9	53.5	4.9	0.009	8.5
			60%	15%	25%	24-S	0.62	35.6	4.8	3.6	41.5	1.4	0.013	8.6
150%	150	4½	12%	68%	20%	57	0.09	6.3	19.4	4.2	0.0	0.0	0.005	6.8
			48%	12%	40%	25-S	0.28	19.6	9.1	4.4	0.0	0.0	0.010	6.8
		15	48%	12%	40%	26-S	0.36	27.6	7.4	4.4	11.8	0.4	0.007	6.9
200%	100	3	15%	85%	0	3	0.40	34.4	8.1	5.1	0.0	0.0	0.027	5.6
			60%	40%	0	4	0.44	36.4	11.5	4.4	0.0	0.0	0.021	6.4
		10	15%	85%	0	53	0.41	38.0	6.7	4.5	0.0	0.0	0.032	5.6
			60%	40%	0	50	0.59	52.8	7.7	4.7	5.6	0.7	0.032	5.7
	150	4½	10%	90%	0	11	0.14	11.2	19.1	5.2	0.0	0.0	0.017	6.3
			15%	85%	0	7	0.19	14.8	17.2	4.7	0.0	0.0	0.017	5.2
			40%	60%	0	12	0.47	41.8	12.7	5.6	0.0	0.0	0.028	5.9
			40%	10%	50%	54	0.39	32.4	6.9	4.8	0.0	0.0	0.013	6.0
			60%	40%	0	8	0.54	47.2	19.9	5.0	0.0	0.0	0.023	5.2
		15	15%	85%	0	56	0.22	18.6	13.2	4.4	0.0	0.0	0.012	6.4
			60%	40%	0	52	0.41	34.0	17.6	5.7	7.7	1.9	0.019	6.4
300%	100	3	15%	85%	0	41	0.42	47.0	9.4	3.0	0.0	0.0	—	5.0
			60%	40%	0	40	0.64	78.2	11.9	3.4	0.0	0.0	—	3.9

and fuel feed rate (Fig. 6), and (*2*) the cfm underfire air was varied while the levels of excess air and fuel charging rate were held constant (Fig. 7).

Testing Procedure

Before sampling was started for a given test condition, fuel was burned at the appropriate charging rate and with the required air distribution until gas temperatures cycled uniformly over the fuel charging cycle, and surface refractory temperatures in the arch reached essentially stable conditions. Uniform conditions were maintained throughout the gas sampling and particulate sampling periods.

Fuel Charging Technique

Fuel charges were passed through a double-door airlock and into the combustion chamber through the front-opening charging door. In order to minimize the effects of stoking, the only disturbance to the burning fuel bed was during the introduction of a new charge of fuel. At this time, the partially burned material from the previous charge was moved to the back of the grate and the new charge was spread out over the front section of the sloping grate.

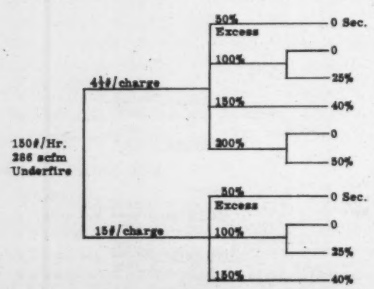


Fig. 5. Test conditions for secondary air.

Results

Results of these tests are quite conclusive in demonstrating the effects of each variable studied on the discharge of atmospheric pollutants. Because the large quantities of smoke and hydrocarbons produced in the furnace were particularly sensitive to temperature levels and the availability of oxygen, the difference between fairly complete and varying degrees of incomplete combustion was quite readily apparent from one test condition to another. The effect on particulate emissions was especially pronounced.

Although these tests were made in a single fixed dimension multiple chamber incinerator, the results can be logically interpreted in terms of basic combustion principles and gas velocities. Under these circumstances it appears reasonable that duplication of these same temperatures, excess air levels, and gas velocities in larger or smaller units of the same general design could be expected to produce corresponding pollutant discharges. Since these tests were made under closely controlled conditions of fuel charging and combustion air distribution, any operational variations from these test levels and experimental procedures could be expected to result in corresponding variations in emissions.

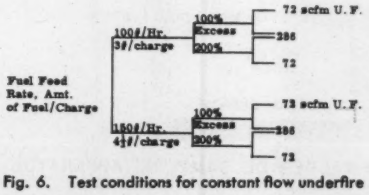


Fig. 6. Test conditions for constant flow underfire air.

It is also reasonable to assume that other high volatile type materials with similar burning characteristics would perform much the same as the asphalt roofing material.

A summary of test results is contained in Tables I and II. Effects of individual variables are reported in the following paragraphs.

Solid Contaminants

Particulate emissions from all conditions tested were consistently higher with the asphalt roofing material than emissions resulting from equivalent test conditions conducted with cellulose fuel.[1, 2] The minimum discharge obtained with the asphalt roofing was 2.6 lb/ton of fuel burned but the loadings from the basic test conditions varied greatly up to a maximum of 47.2 lb/ton for the worst conditions of underfire air, excess air, and fuel feed rate. Under extreme test conditions involving large batch charging, particulates increased up to 65 lb/ton, and the combination of large batch charging with only 50% excess combustion air produced a maximum discharge of 84 lb/ton of fuel. By contrast, the previously reported cellulose fuel tests had a minimum discharge of 0.8 lb/ton

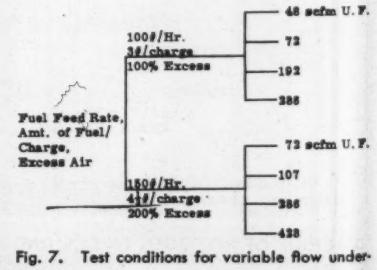


Fig. 7. Test conditions for variable flow underfire air.

Table II—Summary of Average Gas Temperatures

Test No.	Gas Temperature at Thermocouple Position (°F)			
	4	5	6	7
1	1780	1750	1660	1410
2	1850	1860	1770	1490
3	1460	1460	1420	1280
4	1590	1460	1400	1270
5	2000	1950	1890	1770
6	2030	2000	1940	1770
7	1560	1570	1530	1440
8	1510	1490	1410	1300
9	1820	1810	1670	1610
10	1840	1840	1740	1620
11	1540	1530	1510	1460
12	1570	1670	1570	1530
22	2430	2160	2060	1890
22-A	2390	2170	2040	1840
23-S	2070	1940	1810	1710
24-S	2030	1950	1840	1730
25-S	2070	1620	1540	1520
26-S	2040	1640	1540	1520
25	1840	1860	1810	1470
26	1760	1830	1700	1460
40	1130	1050	1000	880
41	1130	1130	1110	970
50	1500	1370	1300	1220
51	1950	1870	1780	1690
52	1600	1490	1440	1390
53	1460	1290	1260	1210
54	2110	1530	1460	1410
55	2010	1830	1800	1710
56	1750	1490	1460	1420
57	—	1600	1540	1500

of fuel burned, and ranged up to a maximum of 9.0 lb/ton under a wide variety of test conditions.

To separate solid particulates into noncombustible or nonvolatile and combustible or volatile components, particulate samples were subjected to a temperature of 550°C for three hours and checked for weight loss. In general, the noncombustible-nonvolatile component of particulate samples amounted to less than 20% of the total weight. Only one test condition (with 40% noncombustible content) was higher, and this occurred under optimum combustion conditions. Tests made at the 50% excess air level had only 5% noncombustible content.

a. Effect of Underfire Air

Results of tests conducted at four levels of underfire air, while all other conditions were held constant, are shown in Table III. For both combustion rates tested there was an increase in particulate discharge with each succeeding increment of underfire air.

Since for each fuel burning rate, combustion chamber detention times were roughly the same and since temperature variations were comparatively small, it can be concluded that underfire air was the sole factor responsible for the increase in particulates. A 500% increase in underfire air produced 320% and 270% increases in particulate emissions at the 150 lb/hr and 100 lb/hr fuel burning rates respectively.

This same trend is further demonstrated by the additional data in Table III which tabulates results of tests conducted at two levels of underfire airflow for each level of excess air and fuel feed rate. In each case, the higher particulate emissions occur at the higher underfire air level.

b. Effect of Excess Combustion Air

In making preliminary tests to establish suitable test levels for different variables it was found that 50% excess combustion air was completely inadequate for achieving good combustion of this fuel. In addition to the discharge of almost continuous black smoke and comparatively high concentrations of carbon monoxide and hydrocarbons, gas temperatures at the bridgewall were excessively high, peaking at around 2400°F. On the other hand, tests conducted with 300% excess air resulted in temperatures too low (1100° to 1200°F) for good combustion, and although there was less smoke under this latter condition than with 50% excess air, it was still continuous. Selection of the 100% and 200% excess air levels was based on these preliminary findings.

As a result of the higher temperatures achieved, combustion was more complete and particulate emissions correspondingly lower on those tests involving 100% excess air than on tests made with 200% excess. Increasing the excess air from 100% to 200% caused an increase in particulate emissions of 140% and 330% at the higher and lower underfire air levels respectively (Table IV).

c. Effect of Fuel Feed Rate

Temperatures produced in tests made at the 100 lb/hr rate were generally lower than those achieved with 150 lb/hr for the same excess air level and underfire air distribution. As a result, the particulate loadings were consistently higher at the 100 lb/hr rate, being 182% more at the 15% underfire level and 18% more at the 60% underfire level (Table V).

Consideration of all factors involved leads to the conclusion that fuel feed rate is only an indirect factor causing either an increase or decrease in particulate emissions. The resulting temperatures and the availability of oxygen are the absolute factors affecting the degree of combustion attained for a given fuel feed rate.

d. Effect of Secondary Air

The term secondary air as used in this study refers to air added to the combustion process beyond the primary combustion chamber. In an effort to reduce and possibly eliminate the effects of other variables, all secondary air tests were made at a fixed fuel feed rate and with a constant cfm underfire airflow. Primary combustion chamber conditions were held constant for all levels of secondary air tested.

Since the basic conditions established in the primary chamber involved only 50% excess air, the resulting incomplete combustion produced unusually heavy solid particulate loadings (Table VI). By increasing the excess air from 50% to 100%, these loadings were greatly reduced whether the additional air was supplied through the secondary ducts

Table III—Effect of Underfire Airflow on Particulate Emissions

Test Conditions: Fuel Feed Rate (Lb/Hour)	Test Conditions: Combustion Air Excess	Test Conditions: Combustion Air Total SCFM	Lb Particulate/Ton Fuel Burned — SCFM Underfire Air: 48	72	107	192	286	428
100	100	320	5.3	14.4	—	15.6	19.8	—
	T_4[a] Temperature →		1785	1825		1855	1835	
	200	480	—	34.4	—	—	36.4	—
	T_4[a] Temperature →			1455			1590	
150	100	476	—	2.6	—	—	13.3	—
	T_4[a] Temperature →			2000			2050	
	200	714	—	11.2	14.8	—	41.6	47.2
	T_4[a] Temperature →			1540	1560		1585	1510

[a] T_4 refers to average gas temperature in degrees F at top of mixing chamber.

Table IV—Effect of Excess Air on Oxides of Nitrogen, Formaldehyde, and Particulates

Test Conditions: Excess Air	Test Conditions: Average Temperature Range (Applies to Particulates Only)	Lb Pollutant/Ton Fuel Burned (Geometric Means of Both 100 & 150#/Hr Feed Rates): NO_2 Cond.[a] 1	NO_2 Cond.[b] 2	Formaldehyde Cond.[a] 1	Formaldehyde Cond.[b] 2	Particulates (Condition 1) SCFM Underfire 72	Particulates (Condition 1) SCFM Underfire 286
50%	—	1.76	2.13	0.008	0.012	—	—
100%	1800–2000°F	4.24	3.99	0.013	0.007	4.6	15.6
200%	1450–1600°F	4.95	4.78	0.022	0.022	19.7	38.2
300%	—	3.19	—	—	—	—	—

[a] Condition 1—3 lb fuel/charge at 100 lb/hr feed rate, 4½ lb fuel/charge at 150 lb/hr feed rate.

[b] Condition 2—10 lb fuel/charge at 100 lb/hr feed rate, 15 lb fuel/charge at 150 lb/hr feed rate.

Table V—Effect of Fuel Feed Rate on Particulate Emissions

Test Conditions: Fuel Feed Rate Lb/Hr	Test Conditions: Average Temperature Range	Lbs Particulate/Ton Fuel Burned: Underfire Air 15%	Underfire Air 60%
100	1450°–1875°F	13.5	26.2
150	1525°–2020°F	4.7	22.2

or added to the overfire air supply. At the 100% excess air level particulate loadings obtained with 25% secondary air were of approximately the same magnitude as loadings obtained without secondary air, indicating that secondary air is no more effective than overfire air in bringing about total combustion for this particular fuel. As further shown in Table VI, succeeding increments of secondary air up to 50% of total flow resulted in increased particulate loadings—the result of additional cooling of the gases.

Results obtained at the 200% excess air level indicate that the lower temperatures produced by this amount of air in the ignition chamber, results in heavier loadings when the air is added to the primary chamber than when the same amount of air is introduced beyond this chamber.

The negligible effect of secondary air noted in these tests may be due to the high degree of turbulence and good mixing of combustion air in the experimental incinerator. Secondary air may be more effective in a larger unit having a lower level of turbulence and less mixing in the primary chamber.

e. Effect of Large Batch Charging

In the burning of conventional fuels, experience has shown that continuous feeding of fuel and air in just the right proportions is essential to achieve the highest degree of combustion from a given fuel. It is only logical that these same basic principles should apply to the burning of waste materials. The charging of large batches of fuel into the furnace serves to quench the burning fuel bed on which the charge is dropped, and excessive volatilization of gases from the new charge produces a back pressure in the furnace which restricts inflowing air. An inadequate supply of combustion air is reflected in increased gaseous and solid pollutants due to the incomplete combustion of hydrocarbons and carbon.

When large batches of fuel are charged into the furnace, burning progresses in the following three stages:

1 On the charging of fuel, rapid volatilization temporarily overloads the furnace with combustible and noncombustible gases and tends to restrict the inflow of combustion air. Varying degrees of incomplete combustion result under these conditions.

2 As the rate of volatilization falls off, a period of very intense burning takes place as the fuel-air ratio approaches optimum conditions. Relatively good combustion results during this interval.

3 As the fuel burns down, burning intensity drops off and there is an increased airflow into the furnace with resultant cooling of the gas stream. This causes a second period of incomplete combustion.

The results of tests conducted at two levels of batch charging for each of several different combustion conditions are shown in Table VII. In all but one of the conditions tested, the larger charges produced higher particulate loadings than the smaller charges. Under optimum combustion conditions tested involving 100% excess air and 150 lb/hr fuel feed rate, the large batch charge resulted in a 125% increase in particulate emissions. The maximum increase amounted to 320% and this occurred at the 100 lb/hr fuel feed rate.

Summary of Particulate Emissions

Results of this study show that solid particulate emissions were consistently greater at the higher levels of each of the following variables:

Excess combustion air (excluding the 50% level)
Amount of fuel per charge
Underfire air

Of all combinations tested, the optimum conditions, as reflected by the minimum particulate discharge (2.6 lb/ton of fuel burned), occurred with the higher fuel feed rate as shown below:

Conditions Producing Minimum Particulate Discharge

150 lb fuel/hour
100% excess combustion air
15% underfire air
0 secondary air
4½ lb fuel/charge

Under these conditions, average gas temperatures in the secondary chamber ranged between 1800° and 2000°F. Any increase in excess air served only to drop gas temperatures below this level and resulted in increased particulate emissions.

Although data collected would indicate fuel feed rate to be a factor affecting particulate emissions, the results obtained are more logically attributed to temperature variations than

Table VI—Effect of Secondary Air on Oxides of Nitrogen, Hydrocarbons, Carbon Monoxide, Formaldehyde and Particulates (150 Lb/Hr Fuel Feed Rate)

Test Conditions: Secondary Air	Test Conditions: Excess Air	Lb Pollutant/Ton Fuel Burned: NO_2 Lb Fuel/Charge 4½	NO_2 15	HC (As Hexane) 4½	HC (As Hexane) 15	CO 4½	CO 15	Formaldehyde 4½	Formaldehyde 15	Particulates 4½	Particulates 15
0	50%	1.76	1.82	3.76	6.50	65.24	143.5	0.008	0.012	58.4	84.0
0	100%	4.45	3.86	0.31	4.92	21.27	53.49	0.008	0.009	13.3	34.0
0	200%	5.58	—	0.00	—	0.00	—	0.028	—	42.0	—
25%	100%	3.60	3.56	0.32	1.41	12.12	41.54	0.006	0.013	14.4	35.6
40%	150%	4.42	4.35	0.00	0.44	0.00	11.84	0.010	0.007	19.6	27.6
50%	200%	4.80	—	0.00	—	0.00	—	0.013	—	32.4	—

Table VII—Effect of Small Versus Large Batch Charges on Oxides of Nitrogen, Hydrocarbons, Carbon Monoxide, Formaldehyde, and Particulates

Test Conditions			Lb Pollutant/Ton Fuel Burned									
			NO_2		HC (As Hexane)		CO		Formaldehyde		Particulates	
Fuel Feed Rate (Lb/Hr)	Excess Air	Underfire Air	Cond. 1[a]	Cond. 2[b]	Cond. 1[a]	Cond. 2[b]	Cond. 1[a]	Cond. 2[b]	Cond. 1	Cond. 2	Cond. 1	Cond. 2
100	100%	15%	5.22	4.66	0.00	3.44	0.00	27.04	—	—	5.3	19.2
		60%	4.00	3.30	0.36	13.40	8.92	75.57	—	—	15.6	65.0
	200%	15%	5.08	4.48	0.00	0.00	0.00	0.00	0.027	0.032	34.4	38.0
		60%	4.36	4.71	0.00	0.67	0.00	5.37	0.021	0.032	36.4	52.8
150	100%	15%	4.13	3.83	0.00	0.64	0.00	0.74	0.009	0.006	2.6	5.9
		60%	4.45	3.86	0.31	4.92	11.27	53.49	0.008	0.009	13.3	32.0
	200%	15%	4.69	4.37	0.00	0.00	0.00	0.00	0.017	0.012	14.8	18.6
		60%	5.04	5.67	0.00	1.85	0.00	7.73	0.023	0.019	47.2	34.0

[a] Condition 1—3 lb fuel/charge at 100 lb/hr feed rate, 4½ lb fuel/charge at 150 lb/hr feed rate.
[b] Condition 2—10 lb fuel/charge at 100 lb/hr feed rate, 15 lb fuel/charge at 150 lb/hr feed rate.

to fuel feed rate per se.

Secondary air (considered at the 100% excess air level) can be used effectively to increase the degree of combustion attained only if an inadequate supply of air exists ahead of the point of introduction of the secondary air. If an adequate amount of combustion air is present in the primary chamber, the addition of secondary air serves only to cool the gas stream and retard combustion. With optimum excess air, secondary air is slightly less effective in achieving complete combustion than an equal amount of air introduced into the primary combustion chamber.

Large batches of fuel per charge generally produce heavier particulate emissions than the smaller charges. These results show that from an air pollution standpoint, small charges at frequent intervals are preferable to large charges at infrequent intervals. There appears to be little question that a continuous feed rate would be the ideal charging procedure.

Oxides of Nitrogen

The discharge of nitrogen oxides increased only 17% when excess air was increased from 100% to 200%. Exploratory tests made at 50% and 300% excess air gave 58% and 25% less (respectively) NO_2* than the 100% excess air tests (Table IV). Reduced emissions at the 50% excess air level can be attributed to insufficient air (providing N_2 and O_2), while the reduction at the 300% excess air level was due to the extremely low temperatures resulting from passing this volume of air through the combustion chamber.

Use of secondary air produced slightly less NO_2 than test conditions which passed all of the air through the primary chamber. At 100% excess, the use of 25% secondary air reduced NO_2 discharge by 19% while at 200% excess, the use of 50% secondary reduced NO_2 by 14% (Table VI).

Although not consistent, NO_2 emissions were generally lower in tests involving large batch charges than in tests made with small charges of fuel (Table VII). The reductions ranged up to 17%. However, tests made with 200% excess air and 60% underfire air produced up to 12% more NO_2 from the large batch charges than from the small charges.

These NO_2 emissions ranging roughly between four and five lb per ton of fuel burned (at 100% and 200% excess air) are approximately double the two to three lb per ton resulting from the previously reported cellulose fuel tests.[2]

From results obtained with 100% and 200% excess air it is apparent that only minor differences in NO_2 discharges occur between the upper and lower levels of the individual variables and between variables themselves. The fact that lower emissions resulted from the 50% and 300% excess air tests would be of practical value in reducing NO_2 emissions only if the other disadvantages resulting from these conditions could be tolerated. Incomplete combustion of carbon occurs under both conditions and the 50% excess air level has the added disadvantage of producing excessively high temperatures.

Hydrocarbons

Hydrocarbon concentration of the incinerator flue gas was monitored continuously with an infrared analyzer sensitized with benzene, ethylene, and acetylene. This instrument satisfactorily detects calibration gases as low as 30 ppm hexane and has an over-all accuracy of ±2% in the 0- to 3000-ppm range. Although this type of instrumentation is not intended to measure total organic content of the flue gases, it is suitable for obtaining comparative data on differences in levels of organics produced under varying test conditions.

Subject to the limitations imposed by this method of measurement, none of the test conditions showed a continuous concentration of hydrocarbons above the lower limit of detectability (about 30 ppm hydrocarbon as hexane). All measurable hydrocarbons occurred in intermittent surges which corresponded with the charging of fuel. Maximum peak concentrations ranged up to 3000 ppm and peak occurrence always coincided with low concentrations of oxygen. Values reported here are averages of these peaks.

Hydrocarbon occurrences predominated at conditions involving 100% or less excess air. Under conditions of 200% excess, HC peaks occurred only on tests involving the combination of large batch charges and 60% underfire air (Table VII). Large batch charges produced much higher loadings than small charges, and emissions (when such occurred) were consistently greater at 60% than at 15% underfire. This effect was most pronounced on tests using large batch charges.

Twenty-five percent secondary air had no effect on hydrocarbon discharge in tests using small charges of fuel, but there was a noticeable reduction with secondary air on tests involving large batch charges. The use of 25% and 40% secondary air gave reductions of 71% and 91% respectively over the hydrocarbon emissions produced in corresponding tests without secondary air (Table VI).

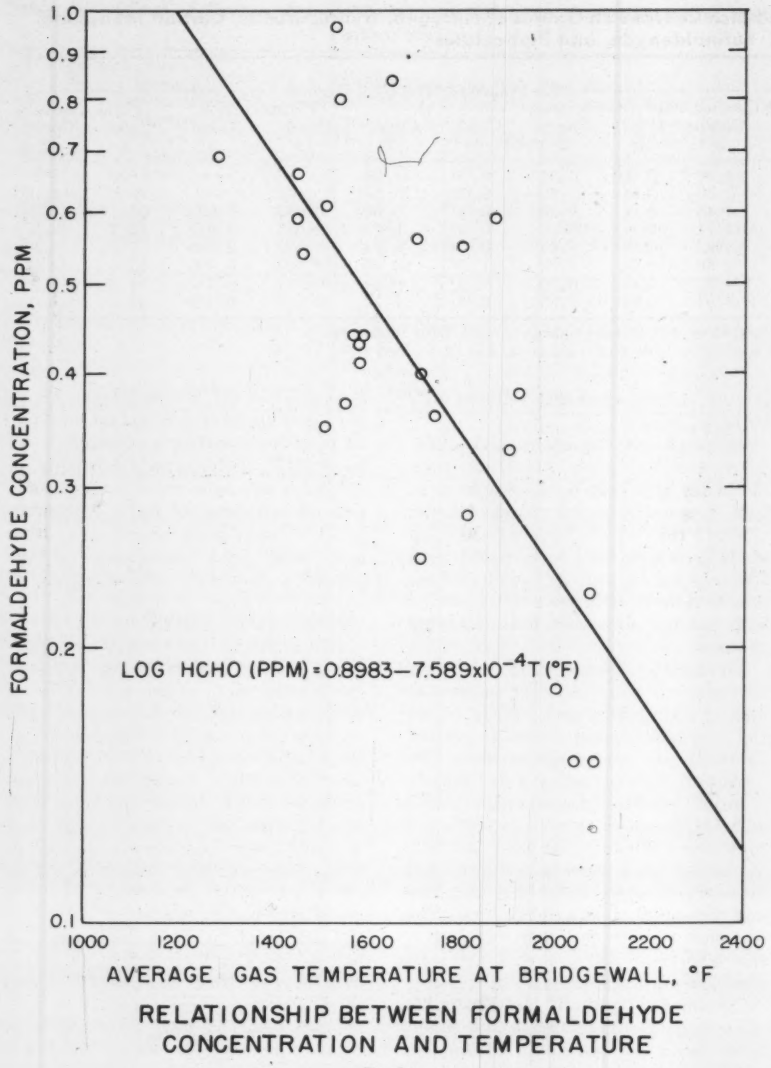
Grab samples of the flue gases taken during the hydrocarbon surges were analyzed by gas-liquid partition chromatography. Components identified included acetylene, ethylene, ethane, propylene, and benzene. Acetylene and ethylene predominated.

Carbon Monoxide

Carbon monoxide generally occurred under the same test conditions that produced hydrocarbons, that is, when insufficient oxygen was available for complete combustion.

The flue gases were sampled continuously with an infrared analyzer having a range of 0 to five percent CO. At no time was there a continuous measurable concentration of carbon monoxide. All values reported herein are the

* The symbol NO_2 is used throughout this discussion to denote oxides of nitrogen, which are determined as equivalent NO_2.



RELATIONSHIP BETWEEN FORMALDEHYDE CONCENTRATION AND TEMPERATURE

Fig. 8.

averages of intermittent surges which occurred for brief intervals (up to 50% of fuel charging cycle) immediately after fuel was charged. Maximum peak concentrations ranged up to five percent CO.

Tests involving 100% excess air and less provided the most consistent conditions under which carbon monoxide occurred. Except for tests combining large batch charges and 60% underfire air, all tests at 200% excess were free of CO peaks.

The discussion relating to hydrocarbons on the general effects of large batch charging, secondary air, and underfire air applies in general to carbon monoxide, as will be noted from the values contained in Tables VI and VII.

Formaldehyde

Formation of formaldehyde was related to combustion gas temperatures, with emissions increasing as temperature decreased. This general trend is demonstrated in Fig. 8, where formaldehyde concentrations have been plotted against bridgewall gas temperatures.

Although the effect of excess air was not completely consistent under all conditions of testing, the trend in those tests involving small charges of fuel was for formaldehyde loadings to increase as excess air increased (Table IV). All conditions for the two levels of fuel feed rate were not tested, but those results obtained indicate that with a given excess air level, formaldehyde emissions were higher at the 100 lb/hr fuel feed rate than at the 150 lb/hr rate (Table VII). There was not a consistent effect due to either underfire air or large batch charges. Similarly, the secondary air effect was not consistent under all conditions tested (Table VI).

Data on the formaldehyde content of flue gases are included here to provide order-of-magnitude information on the occurrence of this compound. However, in interpreting the results, it must be kept in mind that the measurement of formaldehyde by the chromatropic acid method is subject to possible interference from other organics in the flue gases, consequently, the quantitative values presented here may eventually be subject to some modification. On the basis of laboratory evaluations, the possible interference from olefins is considered negligible in view of the flue gas composition, but there still remains the possibility of interference from aromatics in the flue gases. This latter possibility has not yet been fully evaluated.

Smoke

Of the 30 different test conditions evaluated, only one was free of visible smoke throughout the entire fuel burning cycle. This occurred on the same test condition that produced the minimum particulate discharge of 2.6 lb/ton. The degree to which smoke was produced varied with temperature and oxygen concentration. Under certain test conditions, smoke occurred for only brief intervals after fuel was charged while in others the discharge of smoke was continuous. The particulate loadings already discussed are a good measure of the degree of smoke occurrence.

Practically all tests involving 200% excess air produced continuous smoke ranging from No. 1 to No. 3 Ringelmann scale. On the large batch tests, smoke intensity often increased as the fuel burned down and gas temperatures dropped. Any test conditions which dropped gas temperatures in the secondary combustion chamber below 1800°F produced smoke to some extent.

Although gas temperatures resulting from the 50% excess air tests were above 2000°F, the lack of adequate oxygen produced smoke having a No. 5 Ringelmann reading for a short interval immediately after the fuel was charged. A summary of smoke emissions under varying levels of excess air is contained in Table VIII.

Conclusions

These tests demonstrate the difficulty of burning a high volatile solid waste material without making appreciable contributions to atmospheric pollution. The extent to which operational factors affect emissions of different pollutants is emphasized by the wide range of results obtained. From this it is only logical to conclude that minimization of pollutants cannot be affected by proper incinerator design alone but must

Table VIII—Summary of Visible Smoke Emissions

Test Conditions: Excess Air	Test Conditions: Fuel Charging Rate (Lb/Hr)	Test Conditions: Underfire Air	Temperature Range in Secondary Combustion Chamber	Maximum Ringelmann No.	Smoke Duration (% of Charging Cycle)[a]
50%	150	80%	2000°–2400°F	5	25%
100%	100	15 & 60%	1650°–1900°F	3	25%
	150	15%	1800°–2000°F	0	0
	150	60%	1800°–2000°F	2	15%
150%	150	12 & 48%	1500°–1700°F	3	100%
200%	100 & 150	15 & 60%	1300°–1650°F	3	100%
300%	100	15 & 60%	1100°–1200°F	4	100%

[a] Smoke density varied during each cycle up to the maximum Ringelmann No. shown and reading was above 0 for the portion of the cycle reported.

depend on a combination of good design and proper operational procedures.

Because of the basic physical and chemical laws involved, factors shown to affect the increase or decrease of air pollutants in this study would be expected to apply when this or a similar material is burned in other incinerators of different sizes and designs. Since modifying influences can result from many conditions of design, construction, and operation, causative factors brought out by these tests will require individual consideration and treatment.

Reduction of over-all emissions to a minimum will require that optimum combustion conditions be maintained by controlling all operational factors within fairly close limits. Optimum combustion conditions would imply a temperature range of 1800° to 2000°F in the secondary chamber, the use of a relatively low proportion (15% to 20%) of underfire air (the remainder being overfire), and the charging of fuel continuously or in small batches as opposed to large batch charges.

Acknowledgment

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Valley Wind and Pollution Problems

(*Continued from p. 368*)

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COMPLETE SETS OF ABSTRACTS and 1960 PROCEEDINGS AVAILABLE THROUGH HEADQUARTERS

PROBE EVALUATION

(*Continued from p. 363*)

present, pre-flight checking procedures are copied from the hobbyist; but it is foreseen that new testing devices will be designed which will be faster to use and which will provide much more information.

Although the prototype drone has been flown more than 40 times, a sufficient number of consecutive safe flights are needed to give assurance to regulatory agencies that operations can be safely conducted near or even within cities. Ultimately, it is hoped that the aerometric drone will have its instruments and sampling devices calibrated, possibly in a wind tunnel. Then when it is vectored through a plume of air pollution, it will be able to obtain meteorological measurements, particulate or gas samples, and an air quality concentration profile.

Special Note: The following paper describes a pusher - type drone resembling the APER drone:

P. A. Vorontsov, V. M. Mikhel', and A. A. Erler: "Ispol'zovanie radioupravliaemykh aviamodelei dlia aerologicheskikh issledovanii nizhnikh sloev atmosfery" (Utilization of guided model airplanes for aerological investigations of the lower layers of the atmosphere), Leningrad. *Glavnaia Geofizicheskaia Observatoriia, Trudy*, **73**: 107–115 (Fizika atmosfery (Physics of the atmosphere)) (1958).

This reference came to our attention when it appeared in *Meteorological Abstracts and Bibliography*, **10**: 6, June 1959. The USSR drone seems to be adapted directly from a radio-controlled model and records meteorological data rather than telemetering it.

Use of INDEXES *of* AIR POLLUTION POTENTIAL *in* MORTALITY STUDIES*

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Division of Special Health Services, Bureau of States Services, Public Health Service,
Department of Health, Education, and Welfare, Washington, D. C.

The effects of community air pollution on man may be studied in many ways. Among those methods which can be expected to yield significant results is the comparison of the known variation in mortality among metropolitan areas to the variation in air pollution levels. It seems apparent that air pollution levels determined through actual objective measurements of air quality would be most useful in this regard. Although the National Air Sampling Network will eventually provide air measurement data suitable for use with measures of mortality, the air quality data currently available do not readily lend themselves to this purpose.

In the absence of suitable objective air measurement data, attention has been focused on the accumulated evidence indicating that the degree of industrialization and urbanization in general is closely related to air pollution levels. With these available data, it is possible to make rough predictions of air pollution potential by use of factors related to the industrialization-urbanization complex, such as population density and percent of labor force engaged in manufacturing. Some of these measures do exist, and though they are relatively crude, they have indicated a relationship between industrial growth and physical health. Existing measurements, however, do not allow separate consideration of certain specific factors which may be related to morbidity and mortality data, such as types of industries in the urban area, types of fuel in use, and so on.

To compensate for this deficiency, new means of defining the relative amounts and kinds of air pollution in metropolitan areas of the United States have been devised, using readily available data.

These procedures are indirect measures or indexes developed to permit the classification of levels of air pollution and types of pollutants. The Air Pollution Medical Program has prepared a number of air pollution indexes which may be used to differentiate geographic areas with relatively high levels of air pollution from those with relatively low levels of air pollution. These indexes have enabled the Air Pollution Medical Program to supplement its research activities with studies which ordinarily could not be made in the absence of objective air quality data obtained by direct sampling.

One method of preparing the indexes now being used has been outlined in previous presentations.[1] The rationale for the recommended methodology for use in research projects has also been previously discussed.[2]

The indexes are useful. They help determine more clearly the relationship between air pollution and morbidity and mortality, they facilitate epidemiological studies, and they make possible the estimation of air pollution levels through time.

We will present a procedure by which the indexes, as relationships between measures of air pollution potential and selected mortality measures, are evaluated.

Relation of Selected Indexes to Heart Disease Mortality

From a number of indexes prepared by the Air Pollution Medical Program, six indexes were selected which showed:

1. the highest correlation with the remaining source indexes, and
2. in our judgment, the most adequate representation of air pollution potential from those indexes available.

These six indexes were based on: (*a*) all fuel, (*b*) all coal, (*c*) all gas, (*d*) coke, (*e*) SO_2 exhaust emissions, and (*f*) organic exhaust emissions. It was hypothesized that those standard metropolitan areas with high air pollution levels, indicated by those six indexes, would also show high mortality ratios and those with low indicated air pollution levels would show correspondingly low ratios for the following six selected heart diseases: (*a*) chronic rheumatic heart disease, (*b*) arteriosclerotic heart disease including coronary, (*c*) nonrheumatic chronic endocarditis, (*d*) other disease of the heart, (*e*) hypertensive heart disease, and (*f*) hypertension without heart disease. The international classification numbers for specific causes and cause groups are indicated in the appendix. The choice of these six heart diseases was based on (*1*) the availability of precise mortality data and (*2*) their representativeness of heart disease mortality in general.

For each cause of death the 20 highest and 20 lowest standard metropolitan areas by index rank were selected and a comparison was made between the two groups by computing the numbers and percentages of mortality ratios with a value of 1.1 or greater. The results of these computations are shown in Table I-A of the Appendix.

A note on the mortality ratios: the ratio used in this procedure is the ratio of mortality in each standard metropolitan area to that experienced in the total United States, 1949–51. Thus a ratio of 1:1 for a given cause for white males in a given standard metropolitan area means that the white males in that particular area have a 10% excess of deaths over all white males in the United States. Therefore, using mortality ratios with values of 1.1 or greater as a criterion gives a measure of excess deaths.[3]

Comparisons showed that mortality ratios for the 20 highest standard metropolitan areas chosen by the selected air pollution potential indexes were greater than the mortality ratios for the 20 lowest areas by a margin of at

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

least 10% for the diseases: chronic rheumatic heart disease, arteriosclerotic heart disease including coronary, and nonrheumatic chronic endocarditis. Statistical significance was at the five percent level. However, the diseases, hypertensive heart disease and hypertension without heart disease, showed no apparent relationship. Other diseases of the heart showed a negative relationship. Again, this represented a significant difference in proportions at the five percent level. This indicates that our hypothesis does not hold for all the selected heart disease categories under this method of testing.

Relation of Selected Indexes to Cancer Mortality

The procedure which has just been demonstrated was applied next to mortality from cancer.

As before, the 20 highest and the 20 lowest in rank of the standard metropolitan areas, according to each index, were compared in terms of their corresponding mortality ratios for selected disease categories. The working hypothesis was that the highest metropolitan areas would show higher ratios, whereas the lowest would show lower ratios.

Since this investigation was primarily exploratory in nature, several indexes other than those used in the previous section were chosen. This was an attempt to find further relationships with different indexes. As before, the indexes selected were those which manifested high correlations with the other source indexes and, in our judgment, the most representative of air pollution potential from the available indexes.

A total of nine industrial indexes were selected: all coal and coke, all fuel, anthracite coal, bituminous coal, coke, natural gas, manufactured gas, all gas, and coal. In the cancer group, the diseases examined were: cancer of the stomach and esophagus; and cancer of the trachea, bronchus, and lung.

Percentages of those mortality ratios with values of 1.1 and above were computed. It can be seen from Table II that the results clearly indicate that the standard metropolitan areas with the highest indirect air pollution measures for the above mentioned industrial indexes show consistently higher mortality ratios for cancer of the esophagus and stomach—higher in each case by a margin of at least 15%—than do the standard metropolitan areas with the lowest measures. This is completely in accord with the hypothesis.

To make the analysis more comprehensive, the indexes were then correlated separately with the selected disease, cancer of the stomach and esophagus. The results are given in Table III, and it can be seen that all of the industrial indexes showed correlations with cancer of the esophagus and stomach which were statistically significant at the one percent level.

As in the foregoing discussion, the percentages of mortality ratios with values of 1.1 or above for the 20 standard metropolitan areas with the highest air pollution levels indicated by the indexes and the 20 standard metropolitan areas with the lowest levels were computed for cancer of the trachea, bronchus, and lung. Once again, those standard metropolitan areas with the higher air pollution levels showed consistently higher percentages of ratios 1.1 and above—higher in each case by a margin of at least 20%—than did the 20 lowest standard metropolitan areas (Table IV). Correlation coefficients were then computed, as in the previous instance, and again all results were in the expected direction (Table V). In short, a consistent, positive relationship was shown to exist between the indirect air pollution measures given by the nine industrial indexes and the selected disease, cancer of the trachea, bronchus, and lung.

Relation of Selected Indexes to Disease Groupings

Finally, three industrial indexes were investigated with respect to their relationships with disease groupings. The indexes examined were: all fuel, all coal, and all gas. The choice of these three indexes was based on their positive relationships with selected diseases in the foregoing sections and upon their representativeness of air pollution potential sources. The disease groupings were: respiratory cancer, cancer of the digestive system, all cancers, influenza and pneumonia, heart disease, and respiratory disease. These groupings were made to enable the analysis of broad categories of diseases rather than the more specific disease classifications considered in the preceding discussion. The results of the correlation analysis are given in Table VI and it can be seen that the three indexes manifest positive relationships with the three cause groups: cancer of digestive system, all cancers, and heart disease. Some negative relationships were found between the indexes and respiratory cancer, influenza and pneumonia, and respiratory disease including cancer. It should be noted that two of the cause groupings, respiratory cancer and respiratory diseases including cancer, manifest positive relationships for some indexes while negative for others.

Summary

At the present time there are no completely adequate data for categorizing levels of air pollution throughout the United States. Accordingly, a large number of indexes have been prepared by the Air Pollution Medical Program for use as indirect measures to study the possible relationship between these imputed measures of air pollution and mortality. The construction of these indexes is based on potential sources of air pollution such as measures of home heating, specific and nonspecific industry, service station sales, etc. We have demonstrated a particular method in which a number of these indexes can be used as tools for medical research. We have examined the relationships of certain air pollution indexes with mortality from selected diseases and we have shown that positive relationships exist. There are sufficient statistical relationships in this work to indicate the need for further research and study.

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2. Richard A. Prindle, "Some Considerations in the Interpretation of Air Pollution Health Effects Data," *J. Air Pollution Control Assoc.*, 9: 5 (1959).
3. For an example and further explanation of use of mortality ratios of 1.1 or greater see Nicholas E. Manos, "Comparative Mortality Among Metropolitan Areas of the United States," PHS Publication No. 562 (Oct. 1957).

Table I—International Classification Numbers for Diseases Investigated

Disease	International Class. No. (6th Rev.)
Chronic rheumatic heart disease	410–416
Arteriosclerotic and coronary heart disease	420
Chronic endocarditis	421
Other diseases of the heart	430–434
Hypertensive heart disease	440–443
Hypertension without heart disease	444–447
Cancer of esophagus and stomach	150–151
Cancer of trachea, bronchus, and lung	162–163
Respiratory cancer	144–148, 160–165
Influenza and pneumonia	480–483, 490–493
All cancers	140–205
Cancer of digestive system	141, 143, 144, 150–159
Heart disease	410–416, 420–422, 440–443
Respiratory diseases	490–493, 002–008, 161, 162, 500–502, 526, 241

Appendix

Table I-A—Number and Percent of Mortality Ratios 1.1 or Greater for 20 SMA's Rated "Highest" and 20 SMA's Rated "Lowest" by Six Indexes of Air Pollution Potential for Six Selected Heart Causes

Index	Chronic Rheumatic Heart Disease				Arteriosclerotic Heart Disease Incl. Coronary				Nonrheumatic Chronic Endocarditis				Other Diseases of the Heart				Hypertensive Heart Disease				Hypertension Without Heart Disease			
	Highest 20 Areas		Lowest 20 Areas		Highest 20 Areas		Lowest 20 Areas		Highest 20 Areas		Lowest 20 Areas		Highest 20 Areas		Lowest 20 Areas		Highest 20 Areas		Lowest 20 Areas		Highest 20 Areas		Lowest 20 Areas	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
All fuel	6	30	2	10	4	20	0	—	6	30	2	10	4	20	14	70	2	10	2	10	2	10	3	15
Coke	7	35	2	10	2	10	0	—	9	45	2	10	5	25	11	55	3	15	4	20	5	25	6	30
All coal	7	35	1	5	3	15	0	—	9	45	2	10	4	20	11	55	2	10	3	15	3	15	3	15
All gas	5	25	3	15	2	10	0	—	9	45	1	5	6	30	10	50	2	10	5	25	5	25	5	25
SO_2 exhaust emission	7	35	5	25	4	20	0	—	6	30	2	10	7	35	11	55	3	15	2	10	4	20	1	5
Organic exhaust emission	7	35	5	25	4	20	1	5	6	30	2	10	6	30	11	55	3	15	3	15	4	20	1	5

Table II—A Comparison of the Mortality Ratios of 20 SMA's Rated "Highest" and 20 SMA's Rated "Lowest" by Nine Indexes of Air Pollution Potential for Cancer of Esophagus and Stomach

Index	Percentage of Mortality Ratios for Cancer of Esophagus and Stomach 1.1 and Above	
	20 Highest SMA's	20 Lowest SMA's
All coal and coke	40	5
All fuel	30	5
Anthracite coal	30	0
Bituminous coal	30	5
Coke	25	0
Natural gas	25	10
Manufactured gas	30	5
All gas	30	5
Coal	35	5

Table III—The Correlations of 11 Indexes of Air Pollution Potential with "Cancer of the Esophagus and Stomach"

Index	r
Coal and coke	0.398
All fuel	0.404
Anthracite coal	0.411
Bituminous coal	0.425
Coke	0.330
Natural gas	0.296
Manufactured gas	0.336
All gas	0.321
Coal	0.394

NOTE: All these correlations are significant at the one percent level.

Table IV—A Comparison of the Mortality Ratios of 20 SMA's Rated "Highest" and 20 SMA's Rated "Lowest" by Nine Indexes of Air Pollution Potential for Cancer of Trachea, Bronchus, and Lung

Index	Percentage of Ratios 1.1 and Above	
	20 Highest SMA's	20 Lowest SMA's
All coal and coke	40	10
All fuel	40	5
Anthracite coal	40	15
Bituminous coal	45	10
Coke	35	10
Natural gas	45	5
Manufacturing gas	40	5
All gas	45	5
Coal	40	20

Table V—The Correlation of 11 Indexes of Air Pollution Potential with Cancer of Trachea, Bronchus, and Lung

Index	r
Coal and coke	0.362
All fuel	0.372
Anthracite coal	0.343
Bituminous coal	0.438
Coke	0.248
Natural gas	0.369
Manufacturing gas	0.277
All gas	0.326
Coal	0.042

NOTE: All correlations, except "coal" are significant at the one percent level.

Table VI—The Correlations of Three Indexes of Air Pollution Potential with Six Causes of Death Groupings

Disease	Index		
	All Fuel	All Coal	All Gas
Respiratory cancer	0.029	0.308[b]	−0.004
Influenza and pneumonia	−0.264[b]	−0.065	−0.076
Cancer of digestive system	0.492[b]	0.390[b]	0.199[b]
All cancers	0.619[b]	0.444[b]	0.179[a]
Heart disease	0.420[b]	0.343[b]	0.066
Respiratory diseases, incl. cancer	−0.081	0.030	0.103

[a] Significant at the 5 % level
[b] Significant at the 1 % level.

In Memoriam...

Dr. Robert E. Swain, Emeritus Professor of Chemistry at Stanford University, died May 31. Dr. Swain was a pioneer in the field of air pollution and he is credited with having solved the problem of damage to crops caused by the smoke and fumes from furnaces in regions of the Western United States.

Dr. Swain is the recipient of the 1959 Frank A. Chambers Award for his achievements in the air pollution field.

Recommendations for DAY-TO-DAY MONITORING *of* ATMOSPHERIC POLLUTION CONTROL EFFECTIVENESS

Informative Report #3

COMMITTEE TI-5, Public Utilities, Thermal Electric Plants, A. C. PASINI, Chairman

For many years now, the electric utility industry has been spending millions of dollars annually to reduce atmospheric pollution. The physical equipment and the operating techniques necessary to effect this have been developed to a high degree of efficiency and reliability. Black smoke, resulting from improper fuel combustion, is practically unknown, thanks to the excellent automatic control equipment available for boilers, turbine-generators, and their associated auxiliaries. Fly ash emissions from stacks have been reduced to a small fraction of their natural uncontrolled quantities by the use of mechanical, electrostatic, or combination dust collectors. Ground-level concentrations of gases and fumes can now be kept well below objectionable levels by carefully controlled fuel-burning techniques and pre-engineered stacks, combining high-velocity discharge with maximum practical height.

Despite the extreme care usually taken by the public utility industry to make their new plants acceptable to their neighbors and to reduce air pollution to a minimum, there is sometimes a tendency on the part of the local population to feel that since a public utility plant is probably the largest potential emitter of air pollution in the neighborhood that it may be guilty. In such cases, it may be desirable for the utility to install monitoring instruments in the neighborhood to demonstrate that the plant is not an actual cause of air pollution. In these cases, it is desirable, if possible, to make air pollution surveys before the plant is put in operation so that these may be compared with results similarly obtained when the plant is operating, to show that the plant is not materially degrading the air conditions. There are many well established instruments from which the ones necessary for such a demonstration in a particular instance may be selected.

Editor's Note: This is informative report Number 3 of the TI-5 Public Utilities Committee. It is a tentative report at this time and does not commit the Association to underwriting the report or give to it any authoritative connotation.

Kindly direct your comments or criticisms to the office of the Executive Secretary prior to August 15, 1962, for consideration by the TI-5 Public Utilities Committee and the Technical Council.

Some of these instruments are tabulated below.

A Instruments Outside of Plant
- *1* Wind velocity and direction indicators.
- *2* Wind velocity and direction recorders.
- *3* Atmospheric - temperature lapse instruments.
- *4* Dustfall collectors (for general area studies).
- *5* Directional dust fall collectors (selective as to direction from which fallout originates).
- *6* SO_2 recorders (available with sensitivity up to a fraction of a part per million).

B Instruments Inside Plant
- *1* Steam-generator combustion instruments.
  - *a* Excess-air recorder (sensitive either to O_2 or CO_2).
  - *b* Smoke-density indicator alarm or recorder.
  - *c* Combustibles recorder.
- *2* Wired-television (or system of mirrors) for viewing stack-discharge from control room.

The particular instruments required, their number, and their location-distribution will vary considerably from one plant to another. While no definite rules or fixed recommendations can ever be formulated which will be universally applicable, certain guiding principles or "landmarks" can be suggested.

In analyzing these, it first must be recognized that many factors enter into the consideration of the selection of instruments for any given steam-electric generating plant. Among the more important of these are: size of plant (maximum output); load factor, capacity factor, and other load-operation characteristics; type of fuel, oil, gas, coal, etc., and composition of fuel (percent sulfur, percent ash, etc.); type of steam-generating equipment, including combustion control, dust collectors, etc.; number of stacks, stack height, and stack discharge velocity; area population density, and distribution and nature of adjacent properties, i.e., industrial, commercial, residential, farming, etc.; terrain, i.e., flat, hilly, mountainous, etc., prevailing weather conditions.

For the purpose of analyzing these various factors relative to day-to-day instrumentation needs, they must be examined for their effect on each type of pollution which can be reasonably anticipated.

Looking first at the broad picture, where pollution of any nature might be expected, a wind direction and velocity instrument is usually required. For plants of multi-hundred megawatt capacity and located in areas of moderate to heavy population density, the wind velocity and direction instrument should be of the recording type. Determination of the correct location for such an instrument is often quite difficult. Certainly the sensing element of the instrument must be located far enough from buildings, stacks, trees, and other large obstructions so that turbulence and eddy currents caused by these objects do not interfere with air flow at the instrument. Determining the correct height for the instrument is also important. In level terrain it is normally considered satisfactory for the instrument to be located

at a height of from two-thirds to full stack discharge elevation. In hilly or mountainous terrain, no general rule is applicable; rather each situation must be analyzed carefully, all local conditions taken into account, and the sensing element located where there is the best chance of obtaining a representative indication. In the most difficult situations, it may be advisable to employ an experienced meteorologist or to use a trial-and-error testing program to establish the most favorable location. In some instances, the Weather Bureau of the U. S. Department of Commerce will provide valuable information and even free inspection services with recommendations for the proper installation of such instruments.

Again, from a broad over-all point of view, temperature lapse instruments should be considered under certain conditions, primarily for large plants firing high-sulfur residual fuel oil or coal. If a review of past weather history should indicate frequent atmospheric temperature inversions, then such an instrument would be warranted. In hilly terrain where there is moderate to heavy population density at or near stack discharge elevation, then again a temperature lapse instrument would probably be warranted. Incidentally, in applying such instruments, considerable care must be taken to avoid radiation errors from solar or other external heat sources.

Dustfall instruments will be found necessary in far fewer instances than wind velocity and direction instruments. Their use is also restricted to plants burning solid fuels where combustion produces a relatively large quantity of particulate matter. Large plants burning high-ash coal and not equipped with very high-efficiency dust collectors may need one or the other type of dustfall instrumentation, depending upon the nature of the area. For example, in urban areas where both residential and industrial zones are near the plant, it may be advisable to use directional dustfall collectors in order to demonstrate that particulate fallout originates from sources other than the utility power plant. Even though a plant may be equipped with high-efficiency dust collectors and measurable fly ash fallout in the immediate vicinity considered unlikely, installation of dustfall collecting instruments may be advisable, simply to demonstrate that no appreciable pollution is occurring. In several recent instances, such installations have shown that dust from nearby agricultural operations, pollen, road dust, dead insect remains, tree leaf fragments, etc., make up from 80% to 99% of the material collected in the vicinity of a large coal-fired power plant, where flyash pollution had been predicted by newspapers and others not in possession of the facts. Different types of dustfall collectors, method of installation, and selection of location has been covered extensively in the literature. Also, a number of consulting firms and consulting meteorologists are available for advice in this field. Obviously, all dustfall collection installations should be accompanied by wind direction and velocity instruments.

Good commercial, reliable SO_2 recorders are now available although rather expensive. In general, they are needed only near very large plants burning fuels with moderate to high sulfur content. The decision for their need is based on somewhat similar reasoning to that for dustfall instrumentation. Most recently-designed large plants have taken into account the problem of SO_2 dispersion during the initial design stages. Where airport or other restrictions do not limit stack height, it is possible to design stacks so that objectionable ground-level concentrations of SO_2 can be avoided under practically all weather conditions. It is nevertheless often desirable to locate one or more SO_2 recorders in adjacent heavily-populated areas so as to have available records demonstrating that such pollution is being avoided. Again, wherever SO_2 recorders are installed, wind velocity and direction instruments are also necessary so that the records can be properly co-ordinated.

In regard to in-plant instruments, detailed recommendations should not be necessary today. Practically all large modern fuel-burning steam-electric generating plants are equipped with the best available combustion-control systems. This equipment is fully justified by efficiency considerations and is, therefore, automatically available for atmospheric pollution control monitoring. In many plants, neither smoke density nor combustibles indicating or recording instruments are considered necessary because of the high degree of reliability obtainable from modern O_2 and CO_2 analyzers. In some of the older plants, especially those with stoker-firing or those being used for peaking, variable-load operating, the installation of flue smoke-density recorder-alarms may be worthwhile. Again, each individual case must be studied carefully and only after the particular atmospheric pollution control measures which are really needed are determined, should action be taken.

In conclusion, it should be pointed out that there is never a substitute for good judgment. Recommendations of a general nature can only point the way. Each plant must be carefully studied with relation to the type of operation, the equipment installed, and the nature of the neighborhood in which the plant is to be located. Lack of experience can no longer be used as an excuse for permitting widespread pollution, as numerous well-qualified consultants are available. As a number of very thorough studies made in various parts of the country have demonstrated, freedom from objectionable atmospheric pollution can be designed into the modern power plant even though the fuel being utilized may be of comparatively low quality.

—Prepared by G. W. Bice

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4. Janet E. Dickinson, "The Operation and Use of the Tritilog and the Autometer," *J. Air Poll. Control Assoc.*, 6: 4 (1957).
5. R. H. Sherlock and E. J. Lesher, "Role of Chimney Design in Dispersion of Waste Gases," *Air Repair*, 4: 2 (August 1954).
6. E. W. Hewson, "Stack Heights Required to Minimize Ground Concentrations," *ASME Transactions* (November 1955).

INSPECTORS MAY BE KEY IN SOLVING POLLUTION

The Commissioner of the New York Department of Air Pollution Control believes that building inspectors can be the key to the solution of air pollution problems, reports the Building Officials Conference of America.

Commissioner Arthur J. Benline recently told the 12th Annual School for Building Inspectors that the nature, sources, and ultimate solution to the problem of air pollution are questions which building inspectors can answer. He emphasized that air pollution control "is best achieved by enforcement action at the source of the emission of the pollution." Building officials can identify possible sources. They can suggest means for controlling or eliminating sources before they pollute the air to the extent that they are a health menace.

Contrary to common belief, private sources of air pollution often equal or exceed industrial sources. Improperly installed or improperly maintained boilers, incinerators, flues, stacks, and oil burners are pieces of equipment that may contribute to air pollution. Where installation and maintenance are engineering or construction functions, they are closely allied with codes and standards—which are the building inspector's business.

LARGE REGISTRATION SIGNIFIES GREAT SUCCESS OF 54th ANNUAL MEETING OF APCA IN NEW YORK

A registration of over 800 heralds the success of the 54th Annual Meeting of APCA, which was held at the Commodore Hotel, New York City.

A grand total of 78 technical papers was given at the meeting.

The program included the Board of Director's Meeting, business meeting, control officials conference, president's luncheon, cocktail party and banquet, author's breakfast, inspection tours, and a get-acquainted mixer.

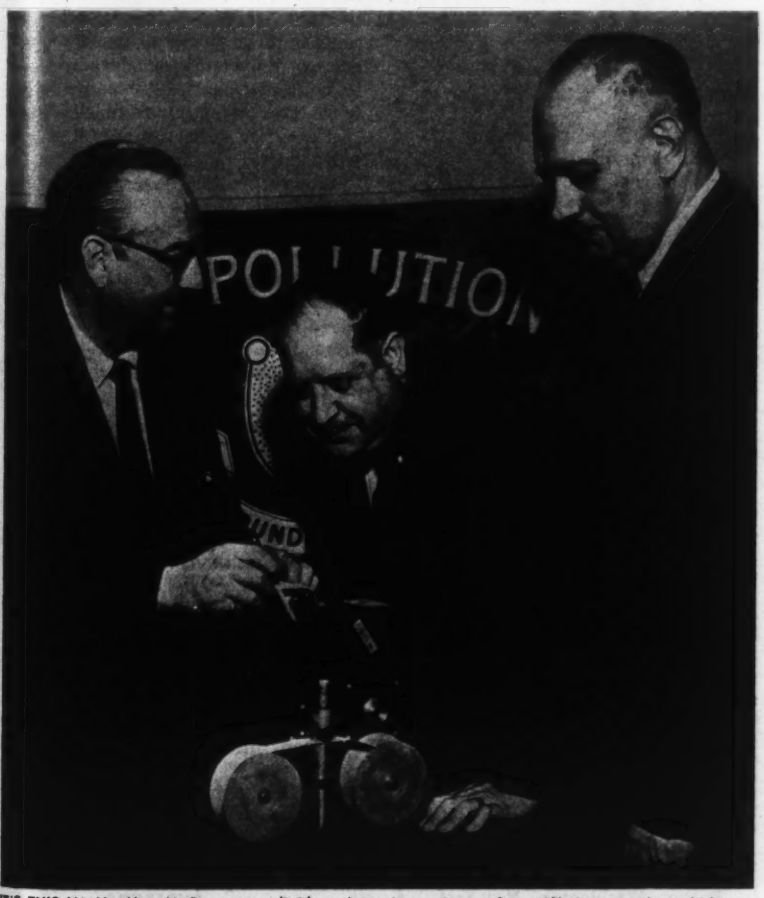
Special features for the distaff side included a coffee hour, visits to the Fiberglas Fabric Center and Steuben Glass Shop, matinee at Radio City Music Hall, breakfast and fashion show in the Charleston Gardens and B. Altman and Company, boat cruise around Manhattan Island, bus tour of International Airport, and farewell breakfast.

The Frank A. Chambers Award was presented to Dr. Philip A. Leighton and Mr. Harry M. Pier was given an honorary membership.

Results of the elections were: W. L. Faith, President; S. Smith Griswold, First Vice President; Morton Sterling, Vice President, Control Officials; R. L. Ireland, Vice President, Industrial Group; V. G. MacKenzie, Vice President, Research; Howard C. Davies, Treasurer, who was elected for the eleventh consecutive term.

U. S. HAS 3 AP LIT CENTERS

With the purchase of a complete copy of the Bay Area Air Pollution Control District's Library Index of 16,850 reference cards by the United States Public Health Service Taft Sanitary Engineering Center, Cincinnati, and by the New York State Air Pollution Control Board, there are now three widely separated centers of comprehensive air pollution literature in the United States: San Francisco, California, Cincinnati, Ohio, and Albany, New York.



IT'S THIS WAY—Moe M. Braverman *(left)* explains the workings of an AISI dust sampler, which was on display at the Annual Meeting, to Executive Secretary Arnold Arch *(center)* and Arthur J. Benline.

NEW SOUTH WALES TO HOLD CONFERENCE ON CLEAN AIR IN '62

A Clean Air Conference, sponsored jointly by the New South Wales Department of Public Health and the University of New South Wales, will be held at the University in Sydney, February 19 to 21, 1962.

The advent of the Clean Air Bill, at present before the State Parliament, has stimulated interest in prevention and control of air pollution.

The major objects of the conference are to provide an initial opportunity for technical discussion of the problems of air pollution, and to supply information concerning the proposed legislation and its administration.

Program

The conference will be separated into two divisions: (*1*) February 19, general and administrative aspects of air pollution control; (*2*) February 20 and 21, technical papers dealing with the evaluation and reduction of pollution.

Broadly, the first division will be suitable for all interested sections of the community, but the second will be directed towards persons with technical training employed in government departments, universities, and industry.

Preprints of papers for all sessions will be available before the conference.

A buffet dinner followed by a film evening is to be arranged at the conclusion of the first day's proceedings.

Registration

Details of registration and conference fee will be made available later. Requests for further information should be directed to the Conference Secretary, Dr. J. L. Sullivan, Chief Scientific Officer, Division of Occupational Health, Department of Public Health.

Welcome New Members

(*Continued from p. 353*)

Miller, Garland M.
Pittsburg, California

Naiman, Estelle
Bronx, New York

O'Brien, Brendan Q.
Chicago, Illinois

O'Brien, John F.
Cleveland, Ohio

Ortman, Gordon C.
Cincinnati, Ohio

Pilcher, J. Mason
Columbus, Ohio

Ramseyer, Donald S.
Minneapolis, Minnesota

Ruth, Joseph P.
Denver, Colorado

Sauer, James A.
Denver, Colorado

Schmitz, Frederick W.
Plainfield, New Jersey

(*Continued on p. 390*)

TA-5 Electrostatic Sub-Committee-Report

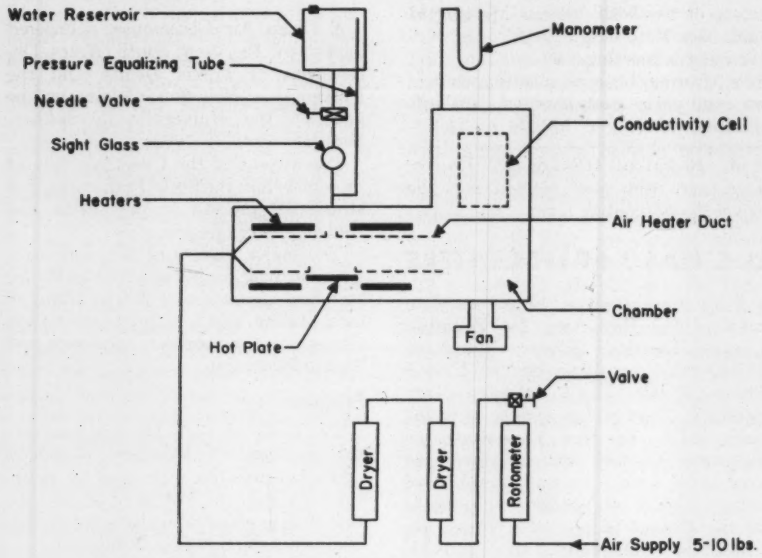


Fig. 1. Schematic diagram, humidity control, bulk resistivity measuring apparatus.

This Sub-Committee recommends that the following addenda to Appendix II of the Randolph report* be published:

(*1*) The proposed method for the bulk electrical resistivity of fly ash is applicable only to materials which have a bulk electrical resistivity in excess of 1×10^7 ohm-cm;

(*2*) The value of breakdown voltage of the dust sample, and the actual voltage at which the data for resistivity calculation are taken, shall be reported with the value of resistivity;

(*3*) An acceptable method for humidity control and measurement is the calibrated water evaporation apparatus shown in Fig. 1. This apparatus comprises a volumetrically calibrated water-dropping device which feeds water to an electrically heated hot plate located in the duct leading to the electric oven housing the conductivity cell. The air (or gas) entering the duct is supplied from a compressed source through a desiccating agent (i.e., $CaSO_4$) and a flow meter. Design of the air (or gas) flow system should allow for approximately eight to 10 changes per hour and provide for the maintenance of approximately one inch of water positive pressure inside the oven.

* "Specifications Required for Design of Electrostatic or Combination Mechanical-Electrostatic Collectors for Fly Ash Collection from Boiler Gases," *J. Air Poll. Control Assoc.*, **8**: 3, 249–259 (November 1958).

Welcome New Members

(*Continued from p. 389*)

Schick, William J.
Cincinnati, Ohio

Smith, Neal J.
Narberth, Pennsylvania

Strumpf, Jerome
Carteret, New Jersey

Swick, William R.
Westfield, New Jersey

Tanga, Giuseppe
Naples, Italy

Thomas, Chester R.
Yakima, Washington

Topham, W. R.
Alloy, West Virginia

Yaffe, Charles D.
Washington, D. C.

Zajaczkowski, Janusz
Warszawa, Poland

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AIR SAMPLING SURVEYS
. PUBLIC RELATIONS

Boston—Washington—New York

RESEARCH COTTRELL, INC. ANNOUNCES SERVICE

Large power savings are made possible by a new engineered service announced by Research-Cottrell, Inc. for converting mechanical and tube rectifiers for electrical precipitators to silicon rectifiers. Payout time for the conversion can be cut at least in half by the new engineered service.

Maximum economic benefits of the conversion are realized by careful evaluation of the complete control system under the new Research-Cottrell engineered service. Large power savings in the control circuit yielded by the engineered conversion save enough over annual mechanical rectifier power costs to pay for the initial cost plus power costs of the silicon rectifier in a minimum of time.

Economical Aids

To insure the most economical operation, proper size silicon rectifiers and control circuit changes are recommended by Research-Cottrell after careful engineering evaluation. Potential sources of trouble are eliminated by a complete circuit analysis. Sufficient circuit resistance and proper relays to prevent overload, adequate control range for maximum output, and correct match of silicon rectifier to both precipitator size and applications are potential trouble sources checked. In some instances it is also possible to comment and advise on the suitability of safety interlocks and instrumentation.

Data Prove Durability

Engineering data obtained from installations dating back to 1956 indicate Research-Cottrell silicon rectifiers will last indefinitely without replacement or maintenance. Electrical efficiency is greater than 98 percent, and a one to two percent over-all daily increase in recovery for the precipitator is made possible by combining the silicon rectifiers with Research-Cottrell's CAS system of automatic voltage control.

The self-contained solid-state units, sealed against moisture and corrosion, consist of silicon diodes enclosed in oil or askarel-filled ceramic cylinders. Capacitors across each diode distribute voltage uniformly during high voltage transient surges.

Preprints Available

$1.00 @ for Members
$1.50 @ for Non-Members
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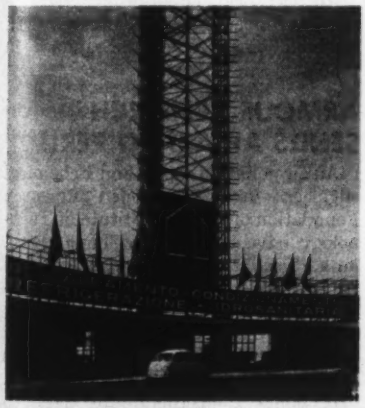
CROWD OF 12,000 VIEWS EXHIBITS AT EXHIBITION HELD IN MILAN, ITALY

◆ ◆ ◆ ◆ ◆ ◆

The Second Heating, Air Conditioning, Refrigerating, and Hydrosanitary Exhibition was held last March in Milan, Italy. In connection with this exhibition, the Second International Air Conditioning Meeting was sponsored by the ASHRAE Italian Branch.

The exhibition was well attended (a gate of 12,000) and featured 85 exhibitors. There was a large and representative crowd of both exhibitors and observers.

At the International Air Conditioning Meeting, various scientific and technical aspects of serious pollution problems were lectured on and discussed. Mr. Gian Bertolinin, President of ASHRAE Italian Branch, reminded the



group, in his opening remarks, of the aims set up at the International Air Pollution Meeting there in 1957. These aims included a campaign to educate the public concerning atmospheric pollution, and the technical and legislative means to be taken; these aims were not achieved.

The meeting was attended by 300 persons, showing the high interest in the present pollution problems that are faced every day by the ASHRAE.

In conjunction with both these functions, the National Contractor's Society sponsored the First National Hydrosanitary Meeting.

SUMMER IS GOOD TIME TO CARE FOR EQUIPMENT

Heating equipment should be cleaned and repaired during the Summer months, according to Commissioner Arthur J. Benline of the New York City Department of Air Pollution Control. Necessary adjustments made now to burner, breeching, chimney, and boiler will not only reduce air pollution from this equipment, but will save money as well.

"New Yorkers can be sure of clean and efficient operation of heating equipment in the months ahead," Commissioner Benline said, "if they will have the equipment cleaned and adjusted now. Smoke is a sign of wasted fuel, as well as a form of air pollution, and proper operation and maintenance of heating equipment will mean fuel savings for the owner, as well as a reduction in air pollution. Costly repairs, overhaul, or replacement can be avoided by good seasonal maintenance."

Free copies of the Department's pamphlet, "Tips on Oil Burner Maintenance and Operating Procedure," are available, in English or Spanish, to those who write to Publications, Department of Air Pollution Control, 15 Park Row, New York 38. Hints on pre-season and seasonal operation of oil burners are contained in the pamphlet.

COUNTY PHYSICIANS FEEL SMOG IN L.A. IS HEALTH MENACE

A recent report that an estimated 2500 persons may have taken their doctor's advice to leave Los Angeles and smog within the past several years, is seen as an endorsement of the Board of Supervisors' policy of dealing with smog as a critical health hazard, according to Air Pollution Control Officer Smith Griswold.

Survey Results

Results of a survey of physicians, made jointly by the Los Angeles County Medical Association and the Tuberculosis and Health Association of Los Angeles County, indicate that 77% of the County's physicians believe that air pollution adversely affects the health of their patients and that an estimated 10,000 patients had been advised to move out of the Basin.

"The air pollution control program in this county has operated on the premise that smog is a menace to health, even though we have never had the medical evidence to prove it," Mr. Griswold said. "Now that the medical picture is taking shape, we already have carried out the most stringent control program possible, and are going full speed to roll smog back to the pre-war level by 1965."

Grim Warning

"Let those opponents of our crash program who advocated waiting until we had more proof of the adverse effects on health, consider where we would be today if they had prevailed," Mr. Griswold said. "This report is a grim warning that we dare not relax."

Next issue . . .

First of the 1961 Annual Meeting Papers will be published.

Regular features to appear:

- Personalia
- Control District News
- Section Hi-Lites
- Welcome New Members
- Calendar
- Secretary's Page

NEWS FROM THE CONTROL DISTRICTS

City of Columbus

Annual inspections of fuel burning equipment throughout the city are being continued. Of the 389 units inspected only 100 required corrections. While it was not necessary to seal units for not complying with our requests for corrections, eight units were sealed at the request of the owners, because they were no longer in use.

The division is receiving many complaints on backyard trash burning and dust from parking lots and building operations, due to warm weather. While this division has no control over residential burning, we try to refer the complaint and/or complainant to the department that can help them, if help is possible.

City Council is helping to keep our complaints at a minimum and the air over Columbus cleaner by their refusals of requests to allow on-site burning within the city.

The Smoke Regulation Engineer attended the "Safety Awards Dinner" of the Greater Columbus Fleet Safety Contest. We were presented two awards, one as a "group winner" and one as a "100% winner." Our accident rate for the year—0.000.

Bay Area

At the 54th Annual Meeting of the Air Pollution Control Association the Bay Area Air Pollution Control District was presented the 1960 award for the "program of public information for advancing the knowledge and practice of air pollution abatement."

In accepting the award, Chairman Andrew C. Byrd of the Bay Area Air Pollution Control District said, "The Directors of the District rely on the people of the Bay Area for their guidance in our interpretations of and wishes to clean up the air in this area. We believe, as a basic fundamental, that there should be no secrets between the people and their elected representatives.

Mr. Byrd Expresses Thanks

"I wish to thank the Air Pollution Control Association for this award, I wish to thank our staff for their efforts, and most importantly, the newspapers and other communication services, who also believe that public information is public knowledge and that public knowledge leads to public wisdom, and that we rely on the public wisdom to assist us in our deliberations."

The Bay Area Air Pollution Control District was one of the five areas which received the award presented by Charles Howison, Chairman of the National Cleaner Air Week Committee of the Air Pollution Control Association at the APCA meeting in New York.

New York City

Bus companies operating in New York City have been warned again about the necessity for keeping smoke and fumes from their vehicles at a minimum at all times. The annual warning came in a letter from Arthur J. Benline, Commissioner of the New York City Department of Air Pollution Control, who stated that infractions of the Rules and Regulations of the Department will certainly result in court action.

The Department's Rules governing the operation of buses prohibit the emission of visible smoke or visible fumes from any vehicle, while it is stationary or while moving for more than 100 yards. In addition, bus drivers are required to turn off the engines of their buses if they are parked for more than three minutes at a route terminal.

"Infractions of both rules must be dealt with severely," Commissioner Benline stated. "The Police Department is co-operating with the Department of Air Pollution Control in enforcing these rules and regulations." Violations of either rule will result in the issuance of a summons and a possible fine of $100 levied for the first offense.

Commissioner Benline reminded the bus companies: "Visible smoke and some gaseous pollutants can be reduced by proper and timely repair and maintenance of equipment, such as fuel injectors, carburetors, fuel pumps, oil rings, and other parts of the engine. Such maintenance will also save the City time and effort in enforcement work and will result in fuel savings for your company."

Allegheny County

Incinerators

The repair work on the Sewickley Valley Hospital incinerator was completed and the unit placed back in service.

An old coal-fired furnace, used as an incinerator by the Neilly Canvas Goods Company, was abandoned.

The incinerator at the Pittsburgh Brewing Company, a source of frequent complaints, was taken out of service.

A performance test conducted on the Pittsburgh Testing Laboratory incinerator proved satisfactory.

The incinerator at an apartment house on Melwood Avenue in Oakland, a frequent source of complaints, was

(*Continued on p. 393*)

Personalia

Jerome Wilkenfeld, Technical Superintendent of the Eastern Chemical Division of the Hooker Chemical Corporation, has been named Chairman of the Water Pollution Abatement Committee of the Manufacturing Chemist's Association, Inc. **Jack T. Garrett,** Industrial Hygienist of the Monsanto Chemical Company, has been named Vice Chairman of the Committee.

* * *

Universal Oxidation Processes, Inc. announces that the administrative offices and laboratories have opened at 526 East 12th Street, Los Angeles, California.

* * *

Ben Ragland has been promoted to a position in charge of future planning, development, and marketing of dust collection and air pollution control equipment of the American-Standard Industrial Division, as announced by A. O'B. Andrews, President. Mr. Ragland will carry the title of Product Manager and will have his office at the Division's home office in Detroit.

Ben Ragland

An electrical engineering graduate of the University of Kentucky, Mr. Ragland joined American-Standard in 1936 as a sales engineer.

ARMOUR RESEARCH SENDS AP AID TO PERU

An air pollution expert and a chemical engineer from Armour Research Foundation of Illinois Institute of Technology have been sent to Lima, Peru, on a special mission to try and rid the air in the Peruvian capital of an overpowering fish odor.

The Armour Research Foundation experts, Samuel Radner, who conducts the monthly Chicago dustfall survey, and James Cooperman, are there to make a technical survey.

The air pollution problem, which has been the source of much complaint on the part of Lima residents, according to Peruvian officials, is caused by the many fish meal producing plants in the area belching smoke and waste products into the air. A special commission, set up by the government of Peru to study and propose a solution to the problem, called the Chicago organization in for advice.

Modification of the processes and installation of collecting or air scrubbing equipment are to be considered as possible solutions to the problem.

FIFTH VOLUME OF SURVEY IS NOW AVAILABLE

The fifth volume in a continuing survey of Russian literature on air pollution and related occupational diseases, being conducted by Dr. Ben S. Levine under a U. S. Public Health Service research grant, is now available to science and industry through the Office of Technical Services, Business and Defense Services Administration, U. S. Department of Commerce, Washington 25, D. C.

Dr. Levine's latest survey of Soviet literature dealing with the air pollution aspects of industrial and public health problems contains translations of 45 articles in six sections dealing with: Russian studies of limits of allowable concentration; pharmacological, toxicological, and clinical data; industrial sanitation; ionization and ultraviolet radiation; benzpyrene; and analytical techniques for measuring various pollutants.

Readers Ask For Analysis

In response to inquiries from readers of the preceding volumes in this series, Dr. Levine has included an analysis of Pavlovian physiology and its potential use in investigations of air pollution in his introduction to Volume 5.

This continuing survey series covers concepts which form the basis of air pollution prevention in the USSR, explains the methods of approach, outlines the scope and plan of the work, and evaluates the progress made. Dr. Levine points out that Soviet interest is both hygienic and economic. The survey shows that industrial discharges frequently contain large amounts of valuable by-products.

CONTROL DISTRICT NEWS

(*Continued from p. 392*)

repaired within 24 hours after a "notice to seal" the equipment was issued.

Open Burning

The Mazzaro Dump, located in Kennedy Township, was converted to a sanitary landfill after several months of negotiations with the owner, township officials, and residents. This terminates perhaps the most flagrant and longstanding open burning problem in Allegheny County.

An extensive open fire occurred at a sanitary landfill operated by the Valley Contracting Company in North Versailles Township which continued to burn for three days. This fire was caused by improper operation and inadequate earth covering of the sanitary landfill.

The gob pile fire located at Bruceton was completely extinguished after adequate earth covering.

PUBLIC HEALTH SERVICE ANNOUNCES STUDIES IN THREE MAJOR CITIES

Intensive studies of lead levels—in the air and in the human system—were launched by health and air pollution authorities June 2 in Philadelphia, Los Angeles, and Cincinnati, the Public Health Service announced.

These studies are the outgrowth of recommendations on tetraethyl lead made by a special advisory committee to the Surgeon General of the Public Health Service. The committee suggested that the Public Health Service, in collaboration with manufacturers of tetraethyl lead and other appropriate organizations, conduct studies to help develop hygienic standards for atmospheric lead and to learn more about the body burden of lead in various selected population groups.

Two types of studies are being made. First, the air over the three cities at several sites is being sampled and measured for the presence of lead contaminants. Second, medical studies are evaluating lead levels in the blood and urine of both average population groups and other groups whose work exposes them to heavy amounts of auto exhaust.

In addition, special studies may be made of carbon monoxide and airborne lead in such locations as garages and vehicular tunnels, where they are presumed to be more concentrated.

TAFT ENGINEERING CENTER TO SPONSOR NEW COURSE

Pollen-polluted air is the subject of a new training course, Sampling and Identification of Aero-Allergens to be presented September 20–22, 1961, by the Training Program, Robert A. Taft Sanitary Engineering Center, major research and engineering laboratory of the Public Health Service, Cincinnati, Ohio. This type of air pollution is a continuing source of complaint and trouble for local governments. Although many conduct seasonal pollen counts, few have programs of sampling, identification, and control. This course provides needed training for professional personnel interested in or responsible for such programs. Course subjects include pollens and fungi, allergen microscopy, and sampling techniques and preparation, with about half the course time devoted to laboratory exercises.

Address applications for the course or requests for information to the Chief, Training Program, Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati 26, Ohio, or to a PHS Regional Office Director.

TRANSATLANTIC CALL TO HI-LITE MEETING

The National Society for Clean Air, London, is holding its 28th Annual Conference and Exhibition in Brighton, October 4 to 6.

A high spot of the conference will be a transatlantic discussion by telephone on air pollution problems between a conference panel and a panel of experts in the U. S. The Society has asked that APCA consider sending three people, a chairman and two speakers, to New York City to participate in the call, which is felt to be the first approach for American interest and collaboration. Tentatively the program will be an unscripted series of questions and answers on air pollution and control, lasting about 30 to 40 minutes.

Emphasis during the Conference will be placed on comprehensive discussions on the operation of the Clean Air Pact in both industrial and domestic aspects. The Conference and exhibition will be opened by the Parliamentary Secretary, Ministry of Power, John George, M.P., and a first Presidential Address will be given by the Right Honorable the Lord Cohen of Birkenhead.

RESEARCH PROJECT LAUNCHED BY PHS

A major research project is now under way which should add valuable information to what is known about the health effects of air pollution. It is a project of the U. S. Public Health Service with the co-operation of the Los Angeles County Air Pollution Control District, and the University of Southern California to observe the effects on laboratory animals—mice, guinea pigs, and rabbits—of breathing the same air breathed by people in Los Angeles County.

The contaminants of primary interest are those specifically associated with automobile exhaust—hydrocarbons, oxidant, carbon monoxide, oxides of nitrogen, and certain particulates.

While the test animals breathe the air at special sites located at varying distances from the heavily traveled throughways, a control group of similar animals will be living in purified air with contaminants removed.

Commenting on the agreement Dr. L. Otis Emil, Division of Air Pollution, Public Health Service, stated: "in this field of study we have long needed careful observations of the effects on laboratory animals of precisely the same exhaust-contaminated air which people breathe. These observations may give us the opportunity to observe in animals, during short periods of time, effects which in human beings might take decades to occur."

PROGRAM FOR EAST CENTRAL MEETING

The East Central Section Annual Technical Meeting will be held September 21 and 22, 1961, The Sheraton Hotel, Louisville, Kentucky. Below is a tentative program for the meeting:

THURSDAY SEPTEMBER 21, 1961

8:00—9:30		Registration
9:30—10:15	"USPHS Programs and Policies"	S. M. Rogers USPHS Washington, D.C.
10:15—10:30		Coffee Break
10:30—11:15	"Area Odor Surveys"	W. W. Stalker USPHS Cincinnati
11:15—12:00	"Plant Odor Survey"	Miles Kaspearic duPont–Montague, Michigan
12:00—2:00	Special Luncheon	Speaker
2:00—2:40	"Process Odor Control"	Procter Gamble Company
2:40—3:20	"Foundry Fume Control"	International Harvester
3:20—3:30		Coffee Break
3:30—4:10	"Municipal Incinerator"	John Leake Director of Sanitation City of Louisville
4:10—4:50	"Process Dust Control"	Ted Kraft Kosmos Cement
4:50—5:50		Business Meeting
6:30—7:30		Cocktail Hour
7:30—12:00		Banquet–Speaker–Music and Entertainment

FRIDAY SEPTEMBER 22, 1961

8:00		Bus Tour of Industrial Area
12:00		Return to Hotel
12:30—2:00	Special Luncheon	Speaker
2:00—2:45	"Maximum Dust Control at a Hugh Power Plant,"	Engineer, Clifty Creek Plant
2:45—		

Coffee Klatch Discussion Groups
1 Municipal Incinerator
2 Dust and Fume Control
3 Louisville APC Operations

Air Pollution Control Association Membership Blank

1. **Name** (or company name).....

2. **Mailing address**.....

3. **Individual members: Company, organization, or agency with whom you are affiliated**.....
   Company or Sustaining members: Industry affiliation or type of business (steel, petroleum, equipment, etc.).....
   .....

4. **Class of Membership (please check)**

		Dues
Individual	☐	**$ 15.00**
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Company Member (National)	☐	**$100.00**
Government Agency Member	☐	**$ 50.00 (Minimum)**
Organization Member	☐	**$100.00**
Sustaining Member	☐	**$250.00 (Minimum)**

5. **Check enclosed herewith** ☐
   Send bill for dues ☐

6. **Company or sustaining member's delegated voting representative is:**
   Name.....
   Title.....
   Address.....

7. **Signed**.....
   Title.....
   Date.....

Here is an opportunity to help your Association get its membership campaign off the ground. Use this application blank for new individual, company or sustaining members. If each APCA member brings in just one new member, we'll be well over the 4000 mark.

APC ADVISORY COMMITTEE SUBMITS REPORT ON STEEL EQUIPMENT TO BOARD

The Air Pollution Control Advisory Committee submitted a report on a program for installation of air pollution control equipment in the steel industry on May 10, 1961. This is in accord with the requirements of Section 1305.9 of Article XIII, of the Regulations for Smoke and Air Pollution Control. The report included and recommended to the Board of Health, adoption of a specific schedule (see table below).

This report has been carefully reviewed by the Health Department staff. The report in essence provides a definite timetable for installation of equipment to control major sources of air pollution from the steel industry. The schedule as recommended requires the utilization of the most modern and efficient engineering devices which have been developed and will practically eliminate the smoke and dust which results from open hearths, electric furnaces, and sintering plants in Allegheny County.

The schedule as recommended will maintain and improve Allegheny County's present leading position in control of steel industry air pollution and also fully meets the requirements of existing knowledge of public health aspects of air pollution from this industrial source. Technological change in the use of fuels and the development of practical engineering control devices has, of course, been involved. Continued effort and support by all will be necessary to maintain the gains made and to reduce further air pollution.

Proposed Steel Industry Gas Cleaning Program Under Section 1308.5 of Health Department's Rules and Regulations, Article XIII. All Figures are % of Total Capacity Tonnage in County

During Year	Open Hearths: Construction Scheduled to Start	Open Hearths: Compliance Scheduled	Electric Furnaces: Construction Scheduled to Start	Electric Furnaces: Compliance Scheduled	Sintering Plants: Construction Scheduled to Start	Sintering Plants: Compliance Scheduled
1960	20	24		30		
1961	5	24	9.8		13	37
1962	18	44	7.8	30		50
1963	0.5	49		5.2	25	50
1964	0.5	67	5.3	47.6	25	75
1965	11	67.5	6.6	52.8		100
1966		68		6.9		
1967	12	79	5.9	64.7		
1968	9	79	6.8	71.6		
1969		91		15.7		
1970		100		84.3		
1971				100		

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Invitation for Submission of Papers

55th ANNUAL MEETING

of the

AIR POLLUTION CONTROL ASSOCIATION

CHICAGO-SHERATON HOTEL, CHICAGO, ILLINOIS

MAY 20–24, 1962

Papers for presentation at this meeting are being solicited, and any interested authors should submit, before October 15, 1961, three copies of the title and abstract to the Chairman of the Committee on Technical Papers and Program:

Christopher E. Barthel, Jr.
Program Director for Foreign Science Activities
National Science Foundation
Washington 25, D. C.

If your paper is selected for presentation by the Committee—three copies, including one clear-cut black original suitable for photographic reproduction, of the complete manuscript must be sent to Arnold Arch, Executive Secretary of APCA, Pittsburgh, Pa., not later than February 1, 1962. This will permit preparation of preprints of all papers in time for distribution at the meeting.

Papers submitted for this meeting may not be offered for publication elsewhere than the *Journal of the Air Pollution Control Association* unless specific written release is obtained from the Association. The Association will, however, give the author not later than three months after the date of presentation of the paper either a firm commitment that the paper will be published in the *Journal* of the Association or a release for publication elsewhere.

55th ANNUAL MEETING

MAY 20–24, 1962

CHICAGO-SHERATON HOTEL

CHICAGO, ILLINOIS

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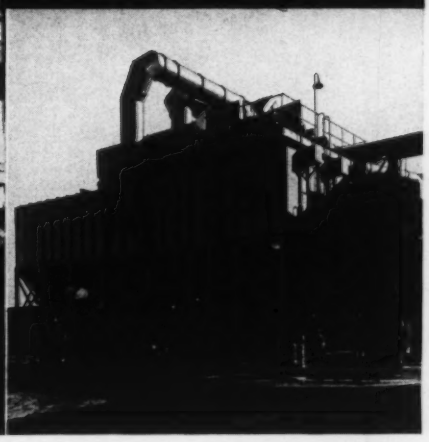
Collecting electric furnace fume is just one of the many capabilities of Dracco cloth filtration techniques. They have been successfully applied to a variety of fume and dust problems throughout the metals industry. If you have an air pollution problem, write Dracco for a cost-saving solution. Dracco Division of Fuller Company, Harvard Avenue and East 116th Street, Cleveland 5, Ohio.

Dracco Filter System labeled "best in the West" by Los Angeles air pollution control authorities

Left: Roof-mounted hood and swivel-type duct connection collect fume from this 25-ton electric furnace during all phases of operation. Controls based on temperature automatically adjust rate of air flow in the system to the changing load.

Below: Four-compartment Dracco Multi-Bag Filter handles up to 75,000 cfm at 225 F. All visible fume particles from three electric furnaces are collected by the unit's Dacron bags. Replacement of six filter bags is the only significant maintenance in four years of operation.



DRACCO *airstream* conveyors
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Kiln Operators with Gas Cleaning Problems on Lime, Coal, Cement, Asphalt or Aggregate

For air pollution control, and for solids recovery from kiln gases, the S-F Venturi scrubber's unique design assures reliable performance without maintenance problems. The Chemico S-F scrubber was specifically designed to permit the recycle of slurries with high solids content. It has no nozzles, trays or jets to plug, and it completely eliminates build-up at the gas inlet.

Chemico S-F Venturi scrubbers are now operating efficiently on kilns throughout the country. For example, a unit installed one year ago on a reburnt lime kiln in California has never caused a kiln shutdown. This Venturi scrubber is designed to handle 35,000 Cfm of hot gases flowing at 450°F. It provides gas cleaning efficiencies of 99%+ on lime dust and 90%+ on soda fumes, resulting in a clean stack.

If you are considering the installation or replacement of gas cleaning equipment, learn more about Chemico scrubbers by writing to: CHEMICO—Gas Scrubber Division. All inquiries will receive prompt attention.

CHEMICO

Chemical Construction Corporation, Gas Scrubber Division
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